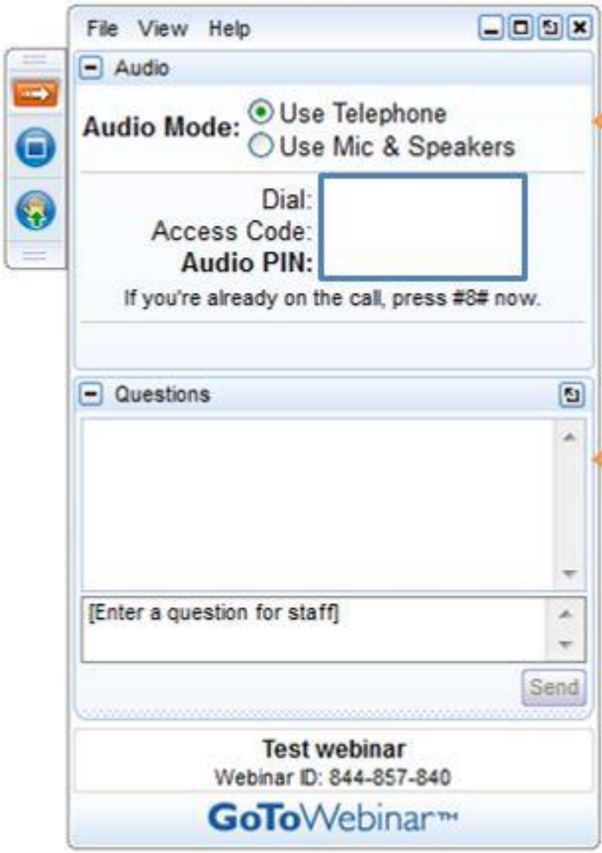
Clean Energy States Alliance and
The Northeast Electrochemical Energy Storage Cluster
Present

Distributed Wind Technology for Hydrogen Production

Hosted by
Val Stori, Project Director, CESA

March 27, 2014

Housekeeping



All participants are in "Listen-Only" mode. Select "Use Mic & Speakers" to avoid toll charges and use your computer's VOIP capabilities. Or select "Use Telephone" and enter your PIN onto your phone key pad.

Submit your questions at any time by typing in the Question Box and hitting Send.

This webinar is being recorded.

You will find a recording of this webinar, as well as all previous CESA webcasts, archived on the CESA website at

http://www.cleanenergystates.org/webinars/

About CESA

Clean Energy States Alliance (CESA) is a national nonprofit organization working to implement smart clean energy policies, programs, technology innovation, and financing tools, primarily at the state level. At its core, CESA is a national network of public agencies that are individually and collectively working to advance clean energy.

About NEESC

The Northeast Electrochemical Energy Storage Cluster (NEESC) is a network of industry, academic, government and non-governmental leaders working together to help businesses provide energy storage solutions. The cluster is based in New York, New Jersey, and the New England States. Its initial formation and development is funded through the US Small Business Administration's Innovative Economies Initiative and administered by the Connecticut Center for Advanced Technology, Inc. (CCAT). The cluster is focused on businesses that provide the innovative development, production, promotion and deployment of hydrogen fuels and fuel cells to meet the pressing demand for energy storage solutions.

Northeast Electrochemical energy storage Cluster

Today's Guest Speakers

Steve Szymanski, Proton OnSite

Tara Schneider Moran, Town of Hempstead, NY

Kevin Harrison, National Renewable Energy Laboratory

Thank you for attending our webinar

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CleanEnergy States Alliance

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TOWN OF HEMPSTEAD, N.Y. NASSAU COUNTY FOUNDED 1644

NREL NATIONAL RENEWABLE ENERGY LABORATORY

PROTON ON SITE

Wind to Hydrogen: Technology Status and Commercial Prospects

Presented by: Stephen Szymanski

Director – Government Business, Proton OnSite

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March 27, 2014

Who We Are: Proton OnSite

- Manufacturer of hydrogen, nitrogen and purified air generators
  - Over 2,000 systems in 75+ countries
  - Market leader in PEM electrolysis

Proton's World Headquarters in Wallingford, CT

Hydrogen Products

Commercial Products

HOGEN™ Hydrogen Generators

S Series

H Series

C Series

Lab Gas Generators

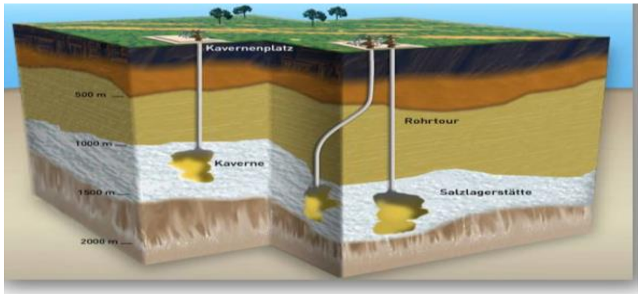
GC

StableFlow Hydrogen Control Systems

Emerging Markets

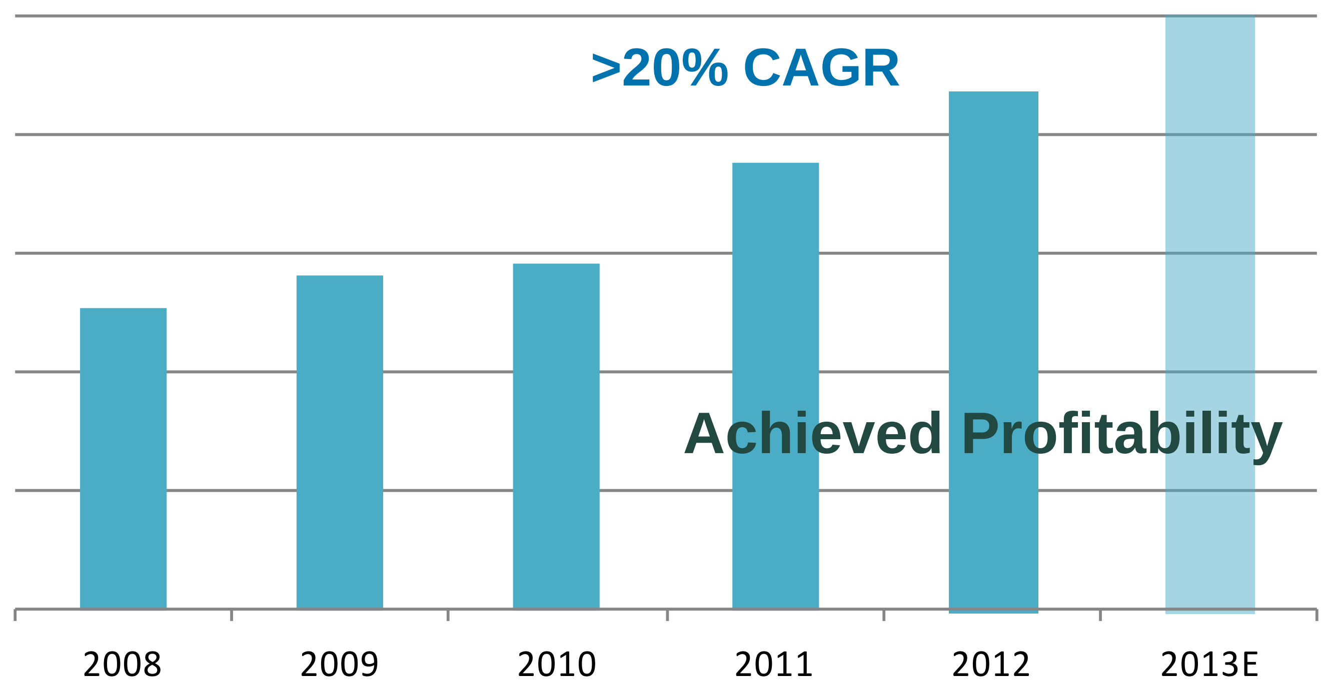
Fueling

Biogas



Renewable Energy Storage

Steady Revenue Growth

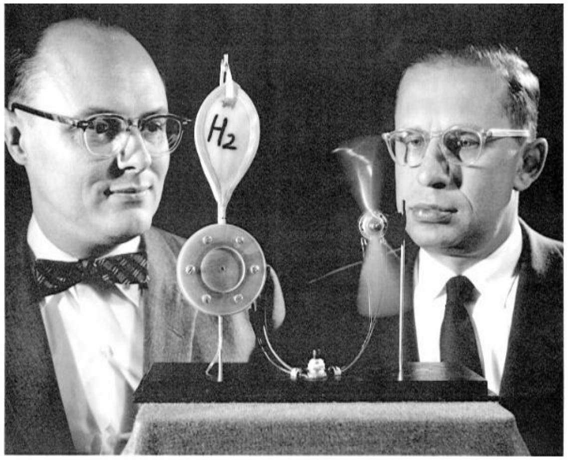


Fueling Growth

- Laboratory market in US and China
- Power plant markets in Middle East, Africa, India and China
- Large projects including containerized solutions
- C-Series for fueling as well as semiconductor applications globally
- **Further growth enabled through larger (MW-scale) products**

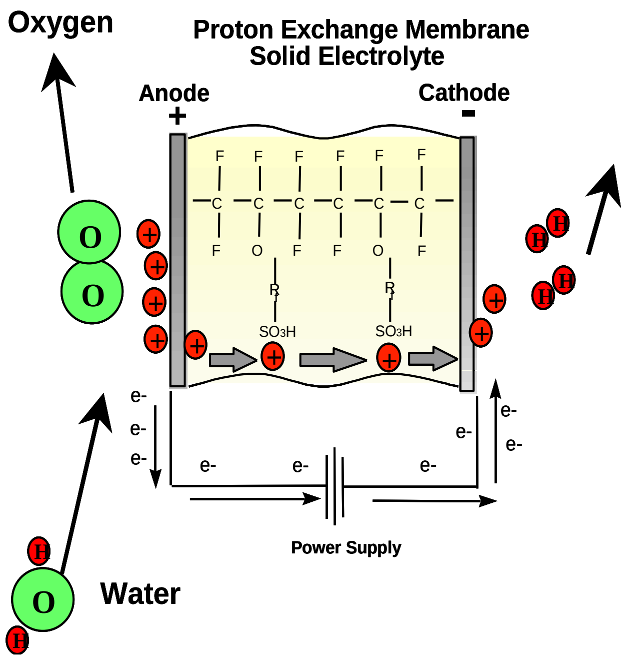
PROTON ON SITE

Fundamentals of PEM Electrolysis

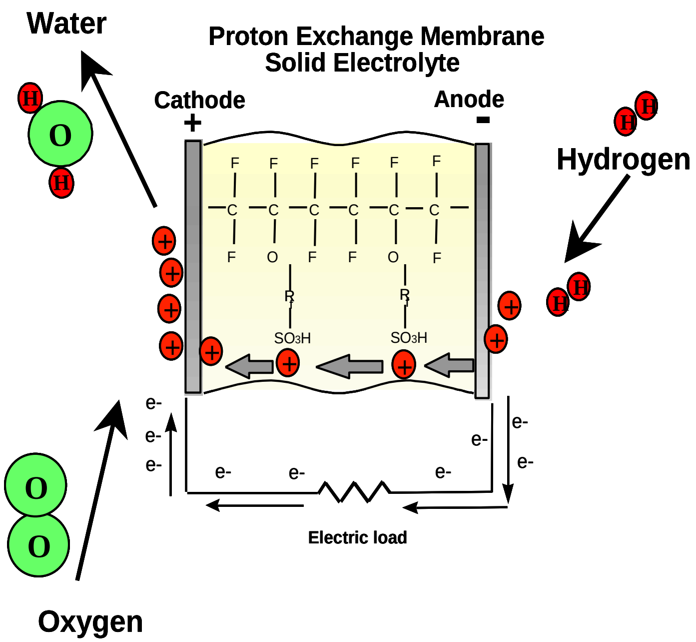


PEM innovators:
Grubb & Neidrach,
GE Research, 1955

PEM Electrolysis



PEM Fuel Cell



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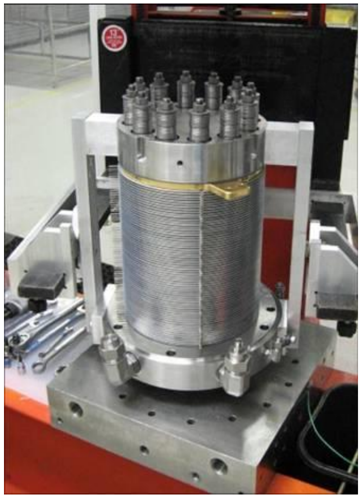
PEM Electrolyzer technology has a long history of reliability in critical military applications:

Oxygen generation for life support: US, UK, French submarine fleets



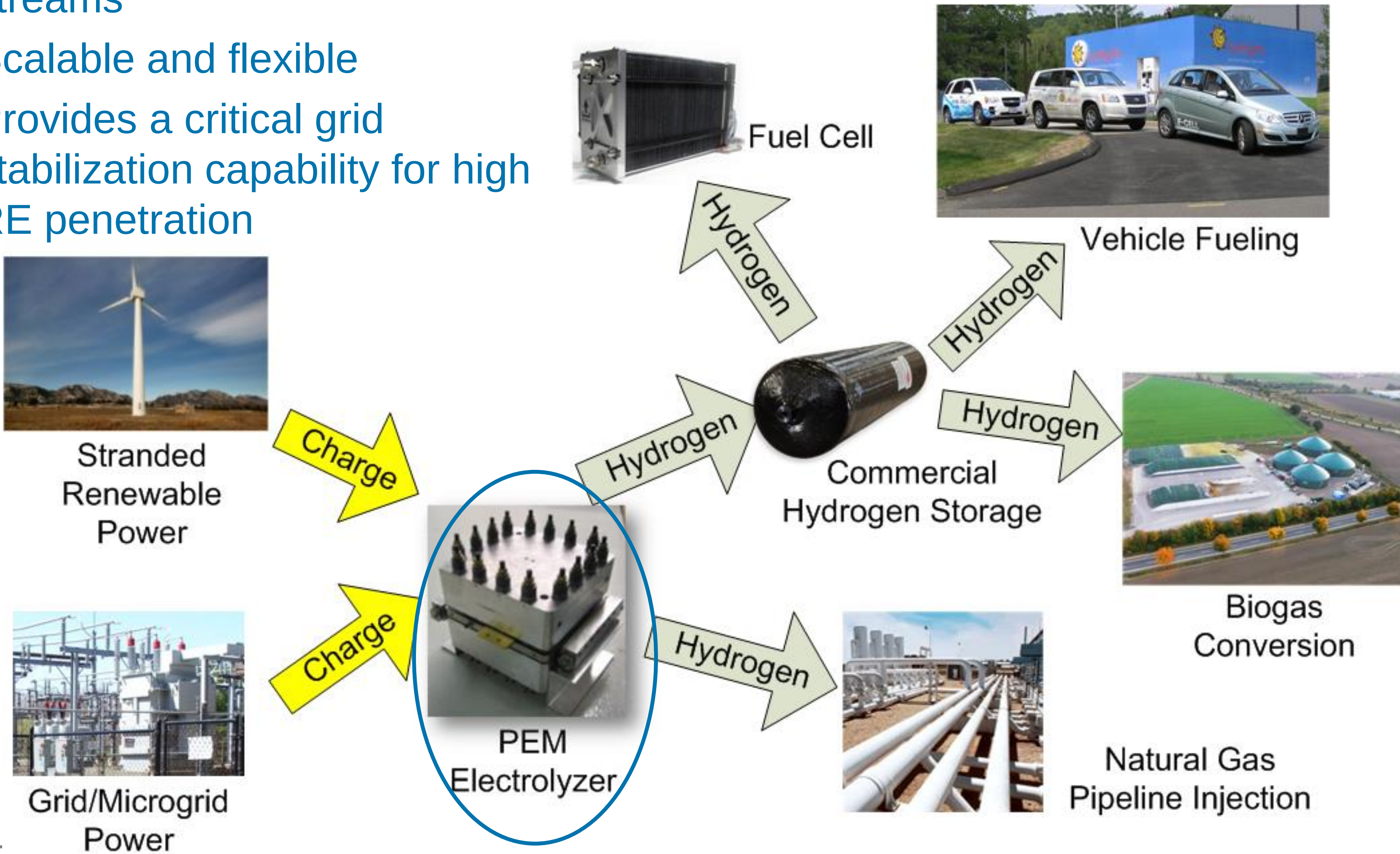
Proton cell stack

Integrated Low Pressure Electrolyzer
Photo courtesy of Hamilton Sundstrand

Virginia Class Submarine

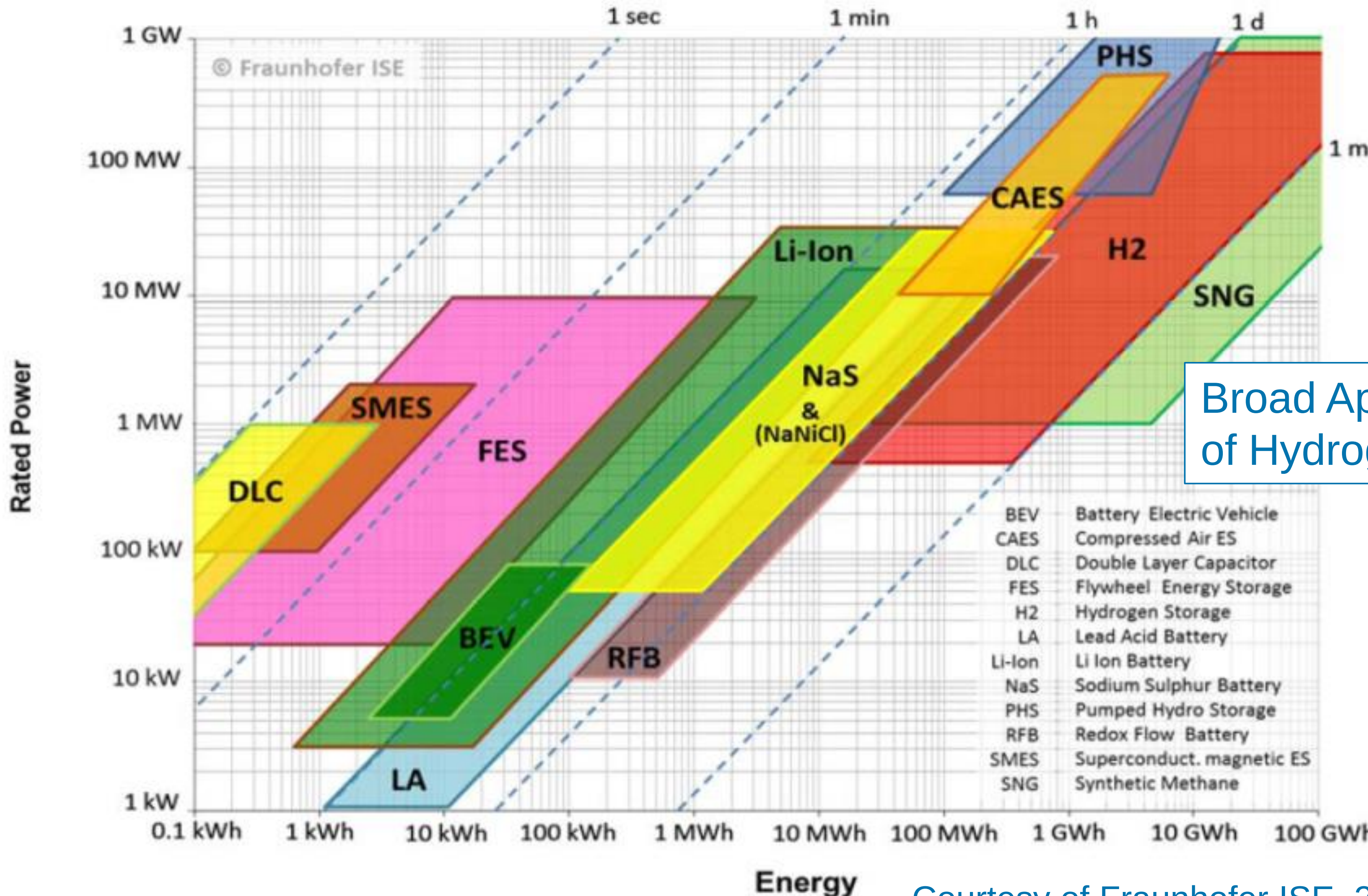
Hydrogen Value in the Energy Ecosystem

- Drives multiple value/revenue streams
- Scalable and flexible
- Provides a critical grid stabilization capability for high RE penetration



PROTON ON SITE

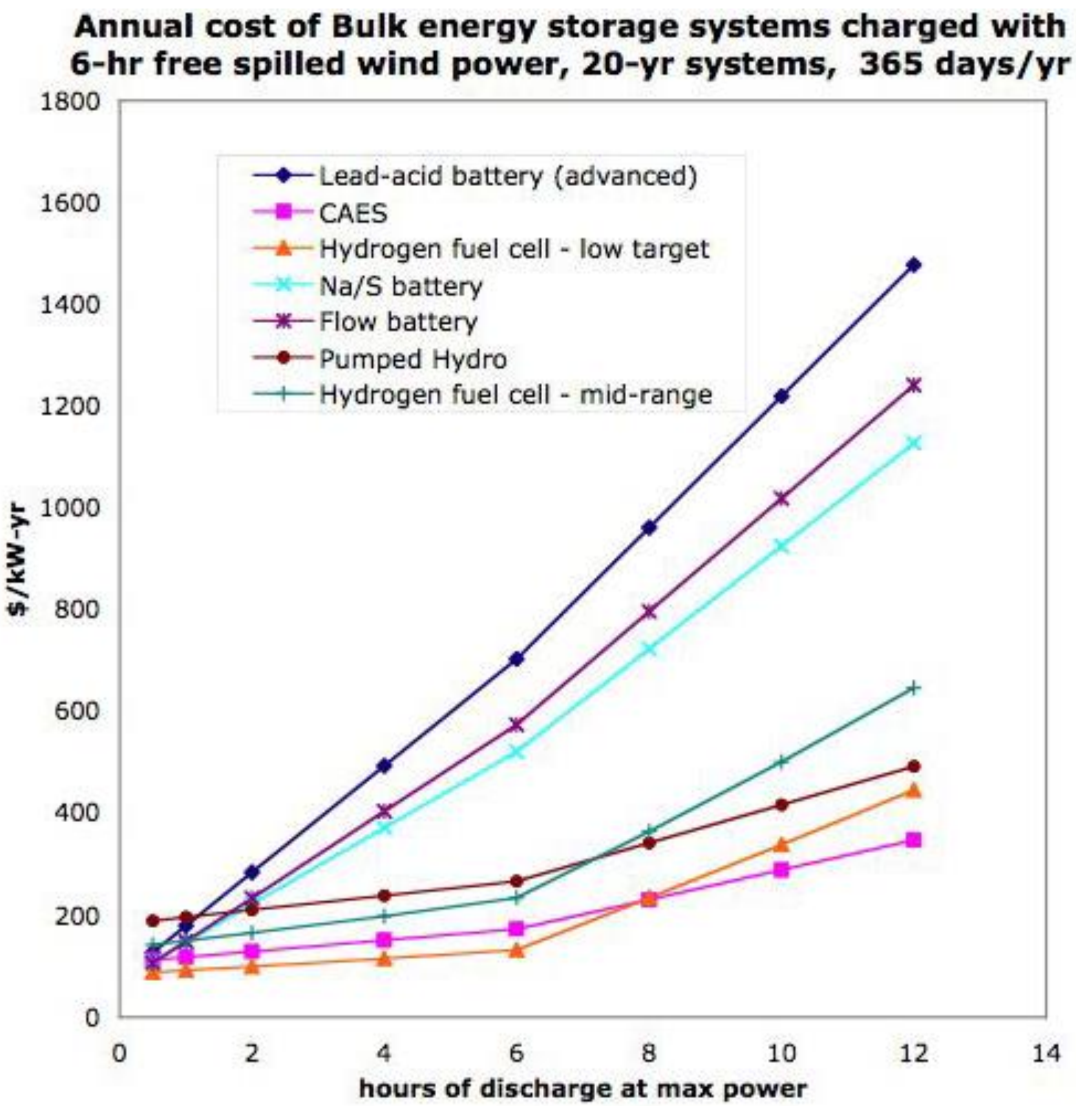
Energy Storage Segmentation Map



Broad Applicability of Hydrogen

Courtesy of Fraunhofer ISE, 2013

Sandia National Laboratory Analysis



Cost analysis shows cost effectiveness of hydrogen ESS

Sandia public report: SAND2011-4845

	Batteries	Electrolysis
Storage Capacity	<10 hours	Expandable with inexpensive storage
Cycle Life	Limited	Unlimited
Cost Challenges	Yes	Leverage fuel cell scale up
Scale	Unproven	100 year technology

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Example: Wind to Hydrogen for Transport

Entegrity Wind Turbines

H6M Electrolyzers at Synthetic Energy

- Synthetic Energy, Idaho
- Stranded Wind to Industrial Hydrogen
- >130000 SCF every two weeks to NORCO via tank trailer

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Example: Wind to Hydrogen to Ammonia

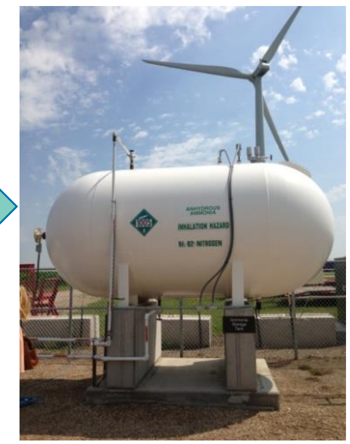
UNIVERSITY OF MINNESOTA
Driven to Discover

University of Minnesota, wind to ammonia pilot plant

Onsite wind power

Proton supplied H2 and N2 generation

Haber-Bosch reactor



Ammonia storage

Market pull for large scale electrolysis:

- Market has emerged in three compelling areas:
  - Conversion of CO_2 from biogas plants to useable methane
  - Storage of renewable energy for grid stabilization
  - Hydrogen fuel for industrial and light duty vehicles
- Each of these are multi billion dollar addressable markets – in Germany alone!
- Proton targeting market entry with 1 and 2 MW electrolyzer building blocks in 2015.

MW Product Overview

- Product size based on input energy capture
- Design approach
  - 1 MW electrolysis modules
  - Power supplies, controls, ancillaries sized a multi-MW scale

MW-scale concept

- Multi-stack architecture per MW
- Large active area stack platform
- Open-frame skid modular configuration
- Capex vs. efficiency trade-off for specific market applications

Large Active Area PEM Stack

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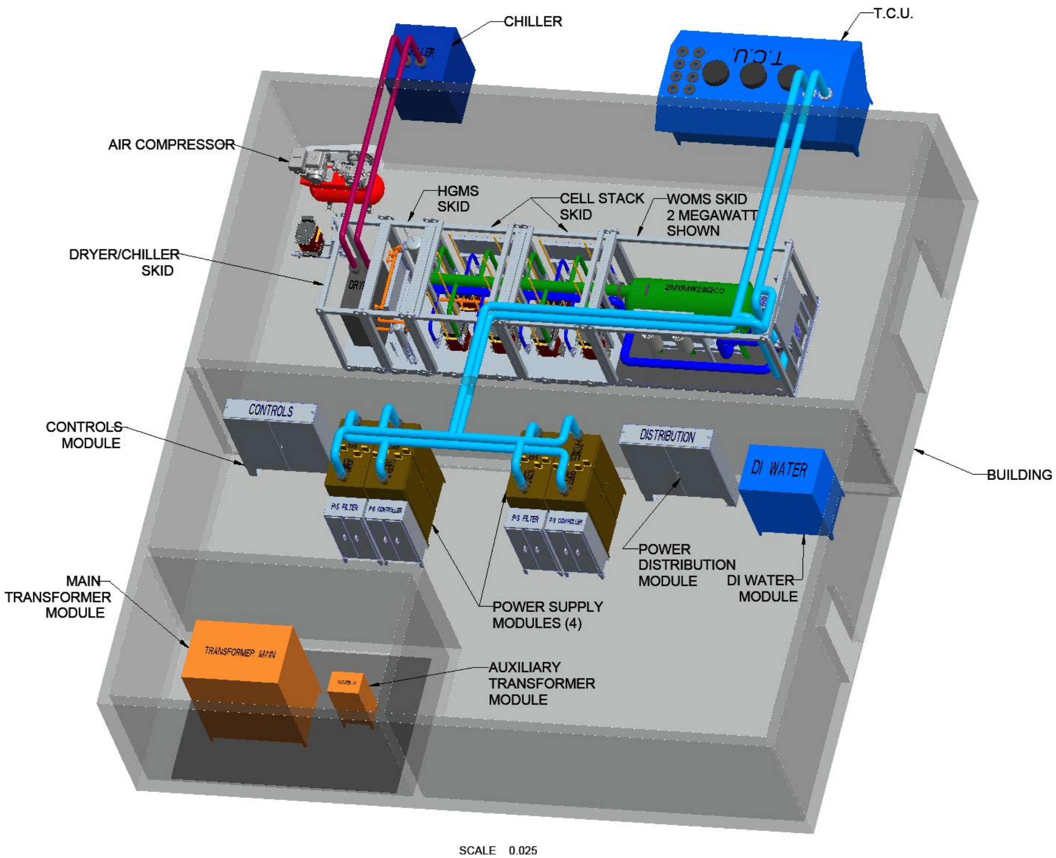
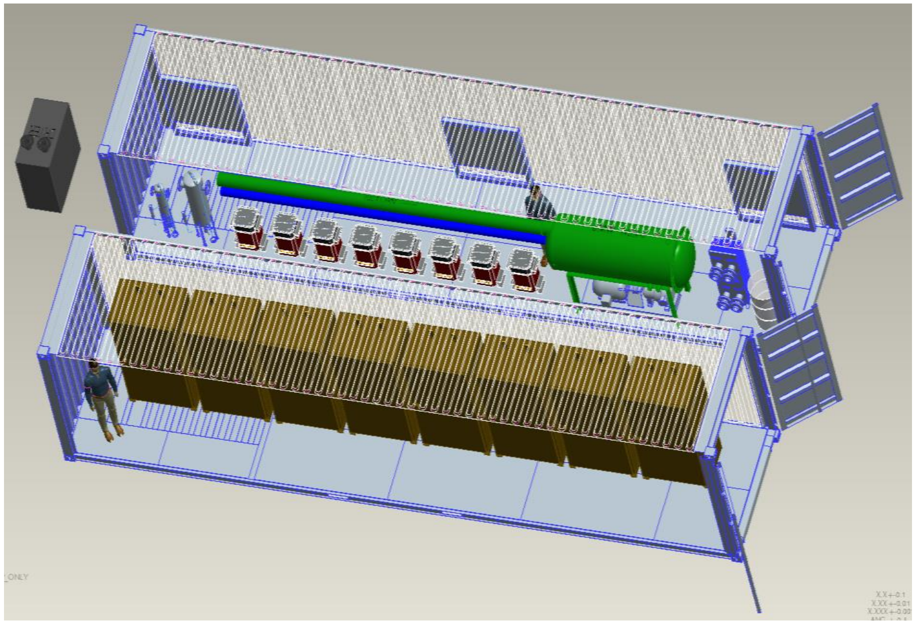
System Concepts (2MW shown)

In Building

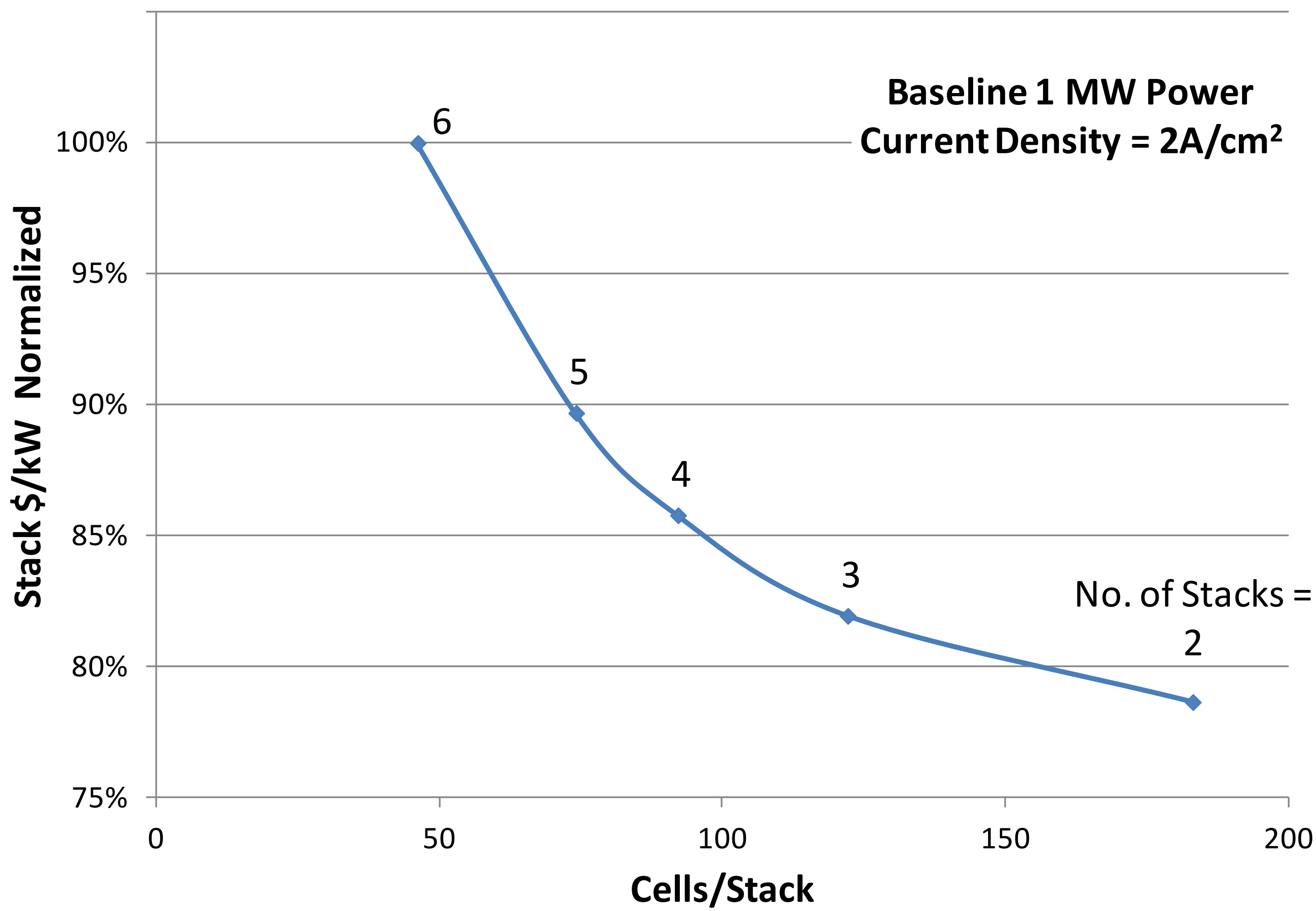


Containerized



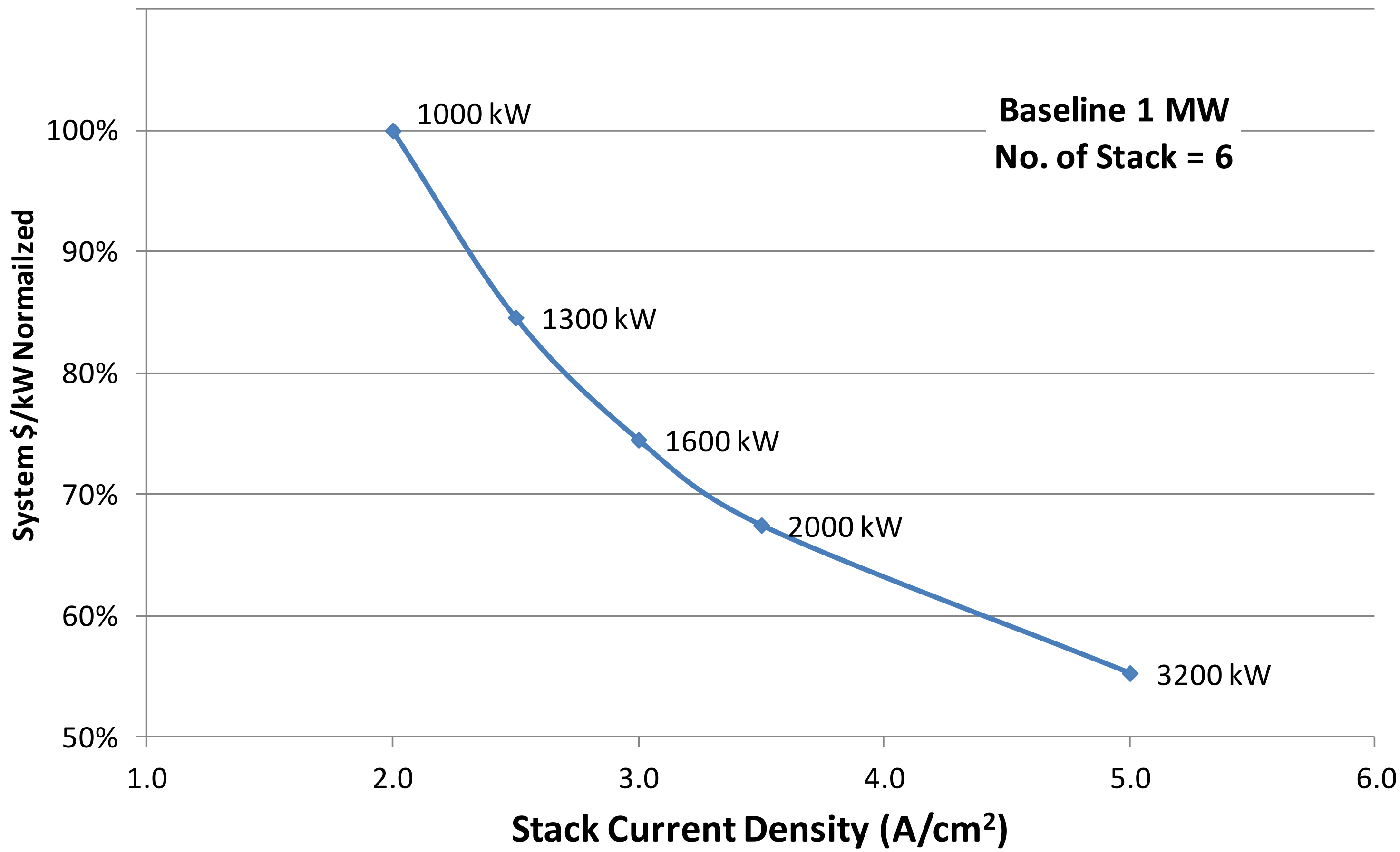
Cost Trade Studies

- Stack cost as function of cells/stack

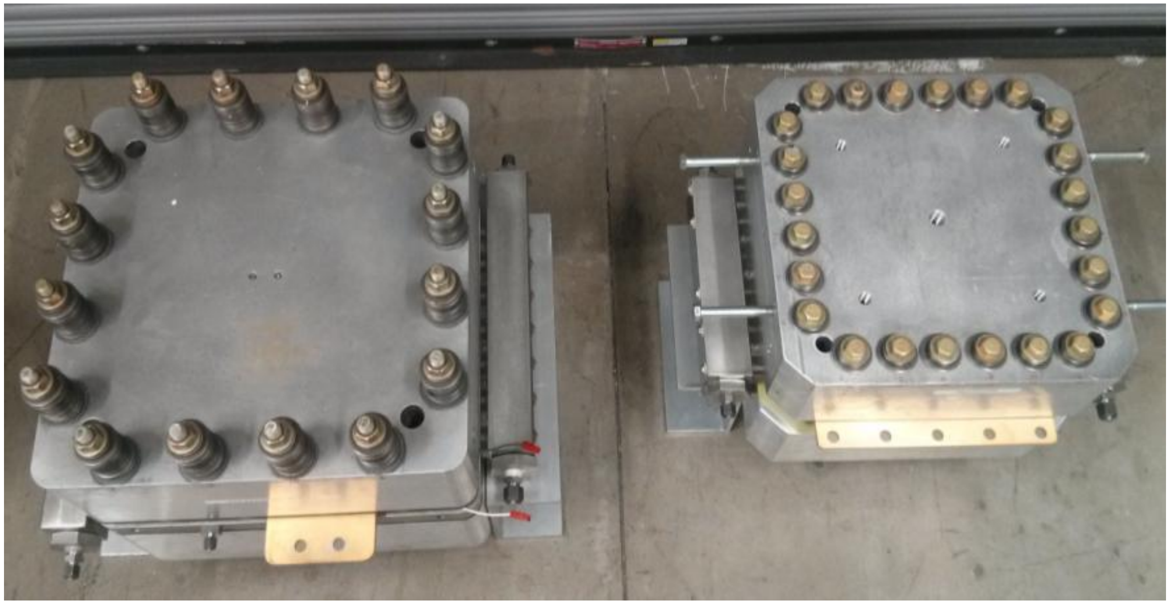


Cost Trade Studies

- Stack cost as function of current density



Cell Stacks Costs Coming Down



Gen 1 Design

Gen 2 Design

- 15% Increase in active area
- Smaller overall footprint
- 40% lower in cost

System Scale-up/Cost Reduction Experience

	HOGEN S-Series	HOGEN H-Series	HOGEN C-Series
Product Type			
Product Launch	2000	2003	2010
Cells/stack	10-20	34	65
Stacks/system	1	1-3	1-3
H_2 Output (Nm^3/hr)	1.05	6	30
$/kW vs. S-series	100%	43%	28%

- Demonstrated scale up of >10X
- Resulted in greater than 70% cost reduction

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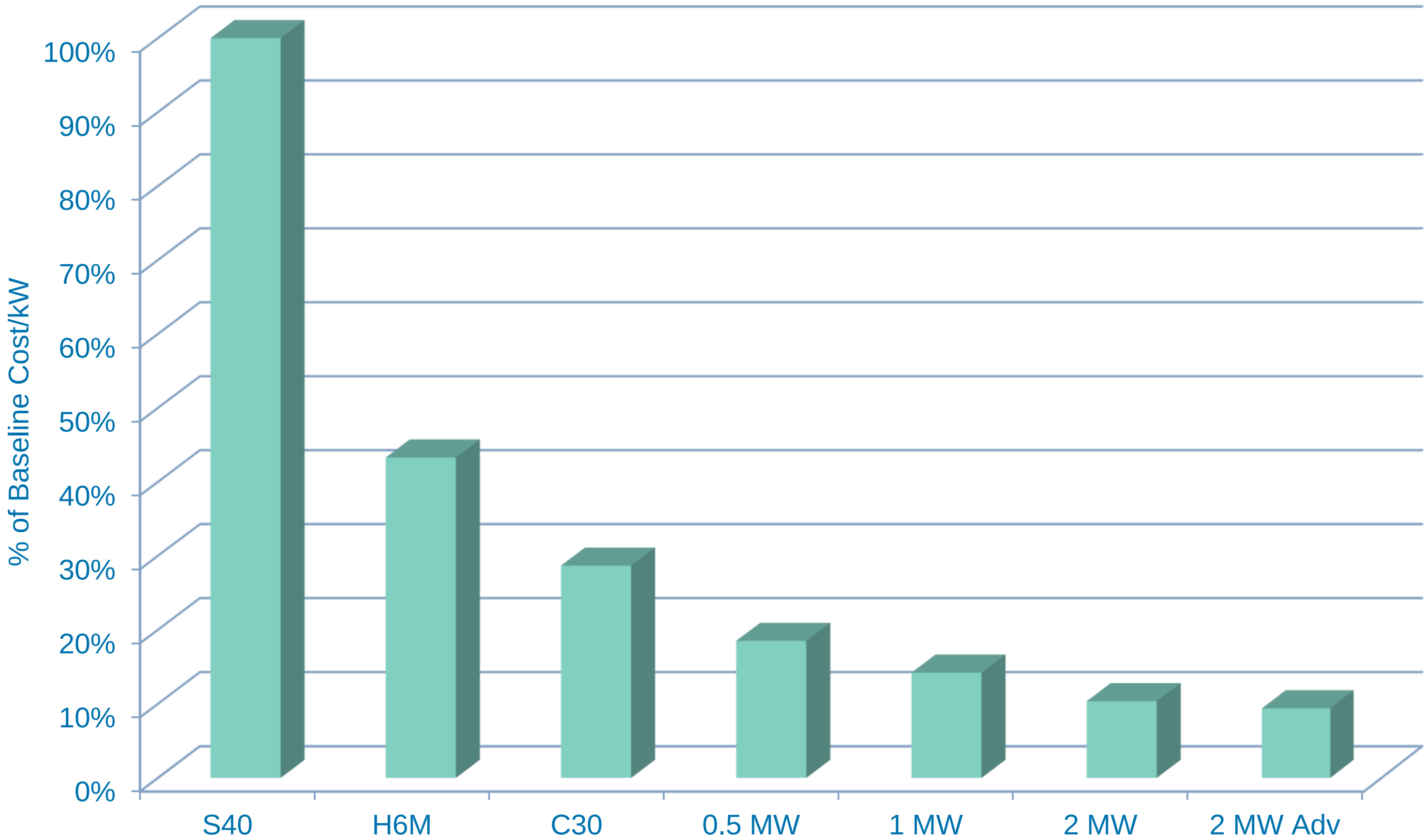
Scale-Up Cost Reduction Trajectory

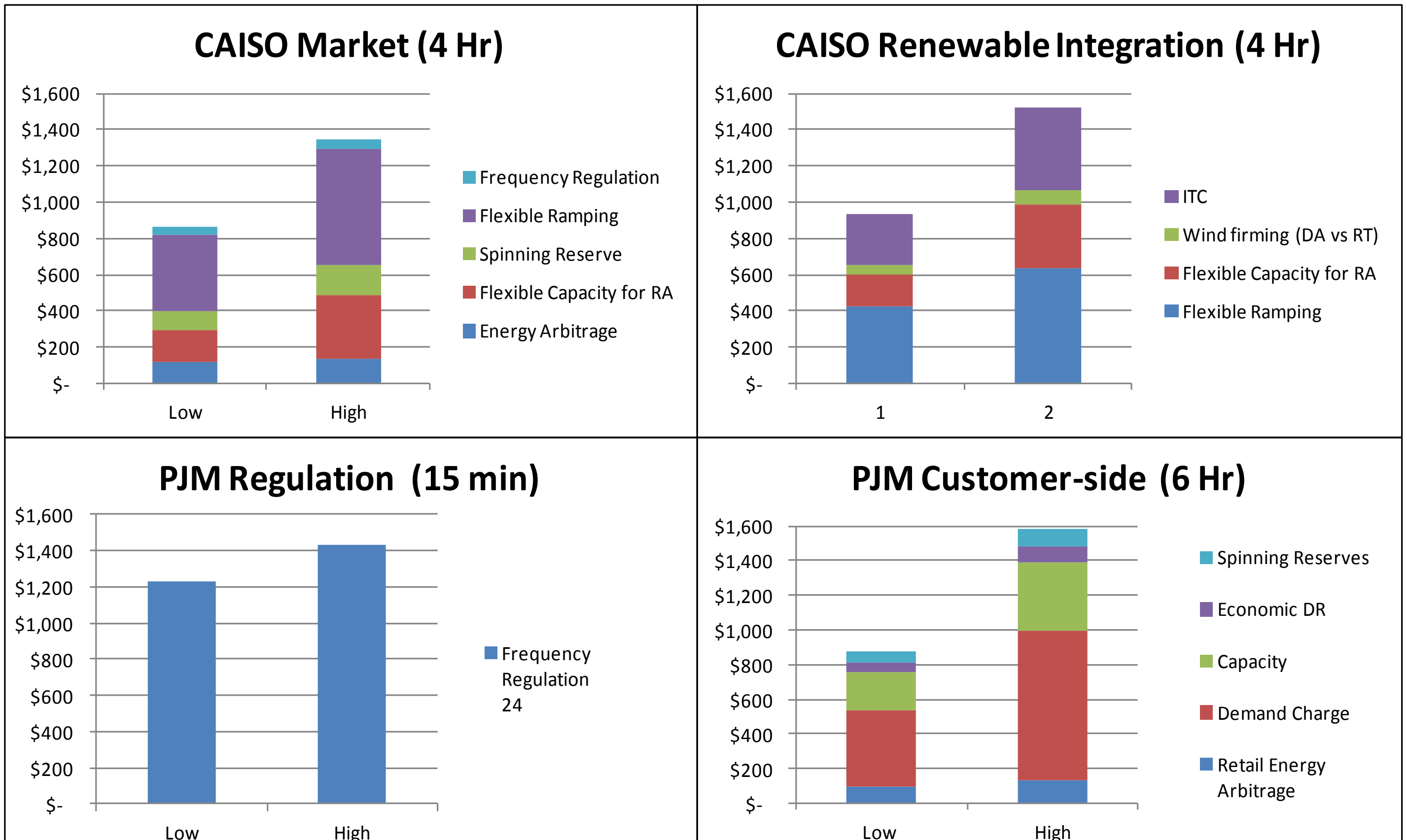


- Straight-forward engineering scale-up of current products
- Critical technology elements already developed

MW Product Market Feedback

- Multiple value stream business model needed

Target System Cost per kW in 2018 (10% IRR, 5 Year Forecast)



Except for frequency regulation, need to stack multiple applications

Source: J. Judson-McQueeny, 2013

Summary

- US has not seen first hand the issues with renewable penetration – like Germany.
- Electrolyzers do not play everywhere but have a role especially for longer duration storage.
- Thinking of the electric grid and the transportation sector as one energy stream is emerging (overseas first).
- The US is lagging most of the world in recognizing and addressing storage.

TOWN OF HEMPSTEAD
PROJECT ENERGY

WIND to HYDROGEN

@ Town of Hempstead Energy Park

Tara Schneider-Moran
Town of Hempstead
Dept. of Conservation & Waterways

TOWN OF HEMPSTEAD

PROJECT ENERGY

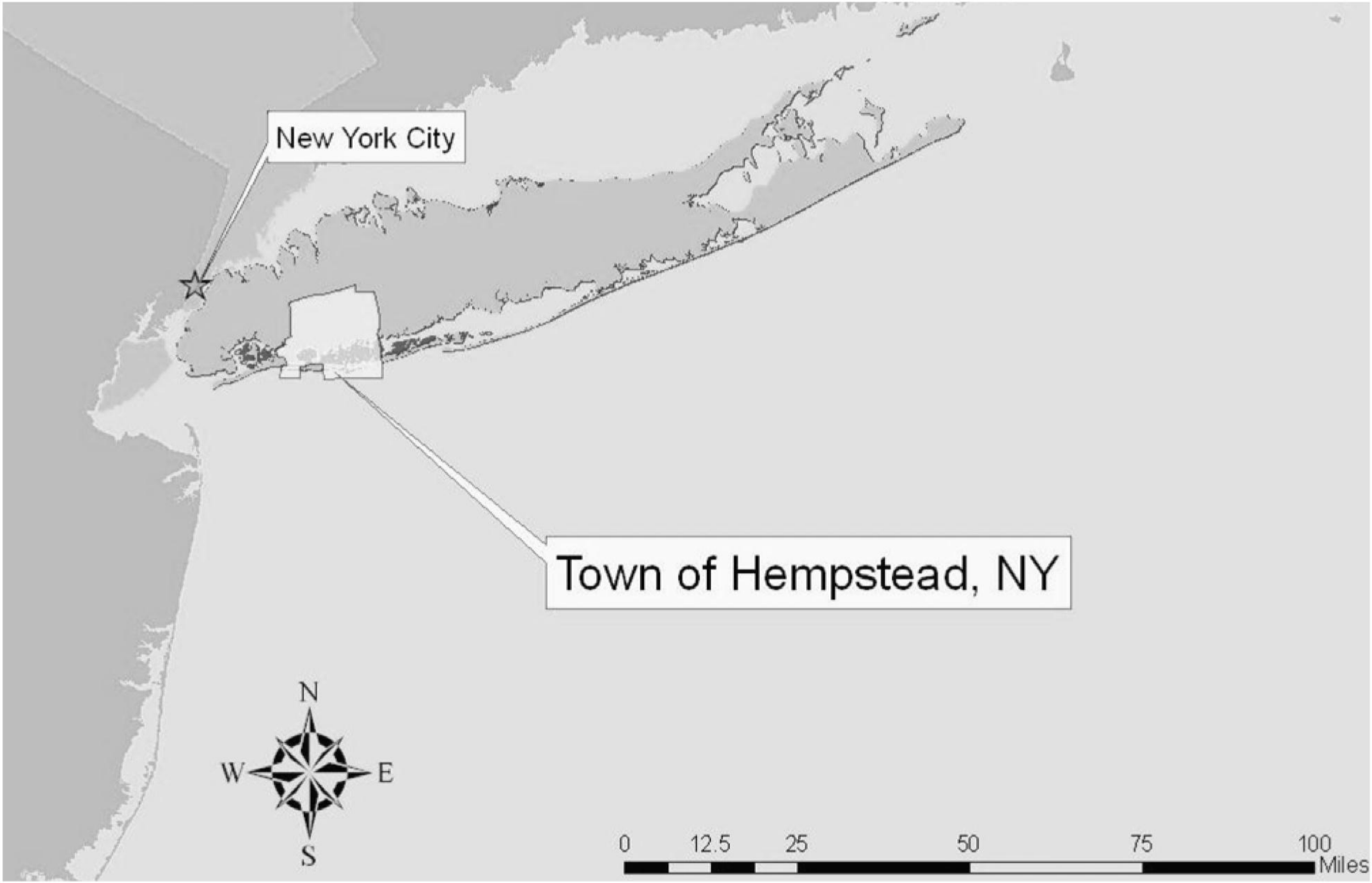
Wind to Hydrogen Background

Hydrogen Station Project Implementation

Wind Turbine Project Implementation

Wind to Hydrogen Present & Future

Presentation Timeline


New York City
Town of Hempstead, NY
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25
50
75
100
Miles

ENERGY PARK Location

TOWN OF HEMPSTEAD
PROJECT ENERGY

ENERGY PARK

Location

Conservation & Waterways

Point Lookout, NY

Outreach for Community

Environmental facility with an environmental message

Model for Others

Data Collection and Monitoring

ENERGY PARK

Solar PV

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ENERGY PARK Solar PV

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ENERGY PARK NYIT Solar House

ENERGY PARK

NYIT Solar House

- Represents various technologies incorporated into one system
- Geothermal, Solar PV, Solar Thermal, Controls System (BMS), Sustainable Materials

Geothermal


West
Marina
Hempstead Bay
NYIT House
Ground Source Heat Pump
2 Geothermal Wells
@ 280 feet
C&W Admin Building
Ground Source Heat Pump
6 Geothermal Wells
@ 280 feet
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ENERGY PARK Shellfish Aquaculture Facility

ENERGY PARK

Shellfish Aquaculture Facility

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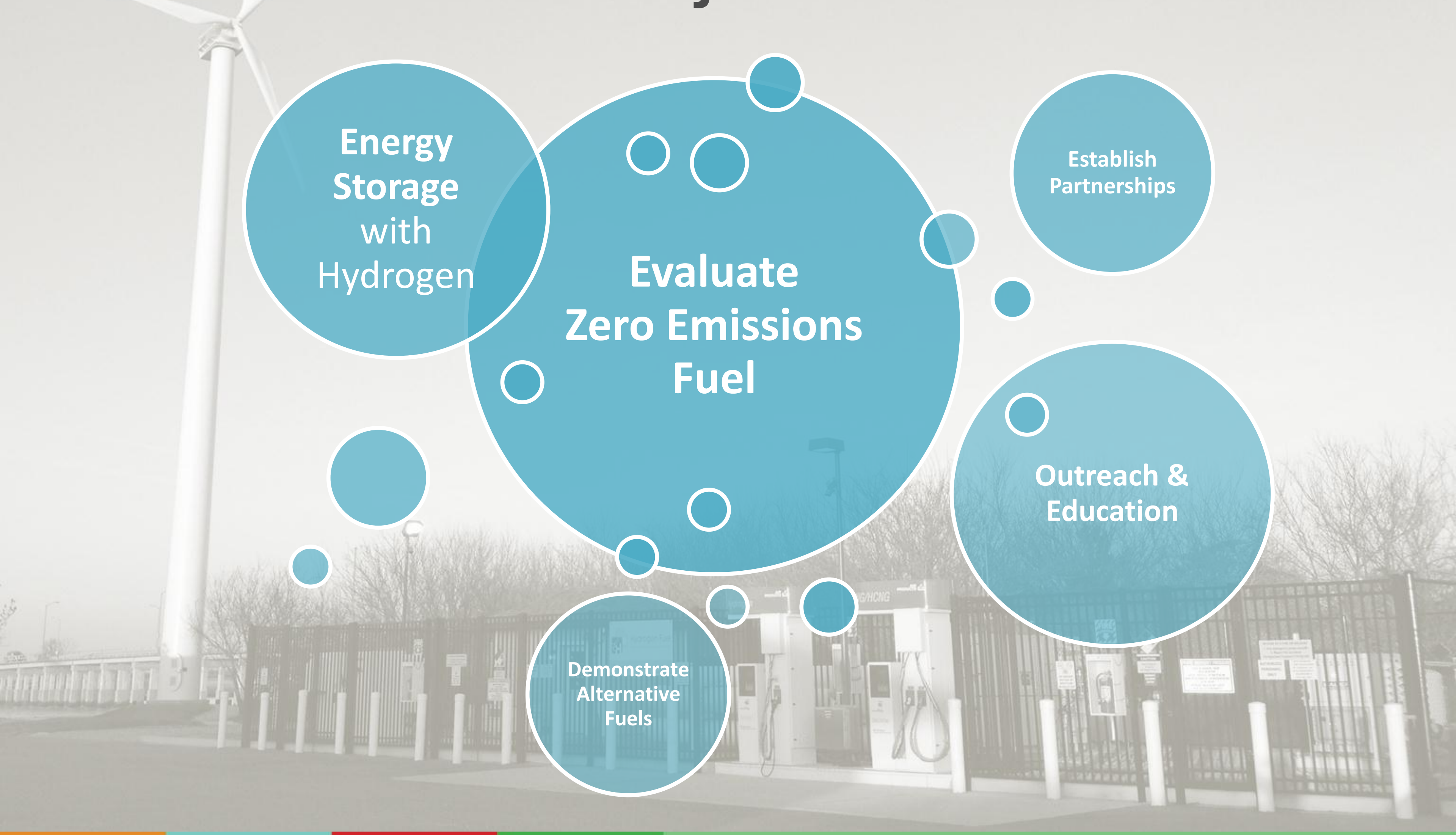
ENERGY PARK **Wind to Hydrogen Project**

WIND TO HYDROGEN Project Goals



WIND TO HYDROGEN

Funding Partners

Hydrogen Fueling Station – Total Cost: $2.1 Million

- **NYSERDA** (New York State Energy Research & Development Authority)
  - PON 1082 – Hydrogen Transportation Development Program
  - Requested proposals that supported the NYS Hydrogen Roadmap and demonstrated HICE technology
- **National Grid** – NYS Alternative Fuels Tax Credit – 50% of total station cost
  - $55,000 R&D grant towards HICE
- **GLICCC/DOE** – CNG Pick-Up Trucks
- **Toyota** – FCHV Prototype Program
- **Town of Hempstead** – Site Construction Cost Share
- **US Merchant Marine Academy**, Kings Point – Technical Support

100 kW Wind Turbine – Total Cost: $613,000

- **Department of Energy** – ARRA EECBG
- **Town of Hempstead** – Site Construction Cost Share
- **NREL** – Technical Support

Contractors

Contractor	Role
Town of Hempstead	Project Management & Site Construction
Air Products	
Sub: **Proton**	Electrolyzer Manufacturer & Integration
PW Grosser Consulting	Professional Engineer
EmPower Clean Energy	Assistant PM, Data Analysis & Outreach Coordinator
Sub: **Bravery Corporation**	Branding & Web Design
Sub: **TM Bier & Associates**	Data Acquisition & Monitoring System
Clean Vehicle Solutions	Ford F250 and E450 CNG/HCNG Conversions

HYDROGEN STATION

Design & Permitting

- Road Opening Permit
- Sewer Connection Permit
- Sewer Discharge Permit
- Fire Marshal Approval

HYDROGEN STATION

Design & Permitting

H2 Discharge Stanchion

Switchgear Housing

H2 Tube Trailer

- 350 Bar vs. 700 Bar
- Electrolyzer Back-Up Power
- Fueling Capacity
- Electric Infrastructure

3 Fuels, Transition to the Future

Hydrogen

- Produced **on-site** with by **electrolysis.** Requires electricity and connection to potable water system.
- Compressed, Stored at 6500psi & Dispensed at **5000psi** (350 bar)

CNG

(Compressed Natural Gas)

- Natural Gas supplied from **existing infrastructure**
- Compressed, Stored on-site, and Dispensed at **3600psi**

HCNG

Hydrogen & Compressed Natural Gas Blend

- **20% Hydrogen, 80% CNG** by Volume
- **Blended on demand** through blending equipment
- Dispensed through distinct dispenser

HCNG & CNG Nozzles

HYDROGEN STATION Major Equipment

Hydrogen PEM Electrolyzer – 12 kg/day

- Proton

Hydrogen, CNG **Compressors**

- Air Products/PDC, Bauer

Hydrogen, CNG **Storage**

HCNG **Blender**

- Air Products

Hydrogen, HCNG, CNG **Dispensers & Nozzles**

- Air Products, WEH, OPI

Proton Electrolyzer

Vehicles

Hydrogen	• Toyota Fuel Cell Hybrid Vehicles (FCHV). Prototypes.
CNG	• Ford F250 Pick-Up Trucks. After-market Conversion.
HCNG	• Ford E450 Shuttle Bus. After-market Conversion.

Hydrogen FCHVs

HCNG Shuttle Bus

CNG Pick-Up Trucks

WIND ENERGY

100 kW Wind Turbine

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WIND ENERGY Information Gathering

- Motivated by Commissioner Ron Masters
- LIPA **Feasibility Study** on Wind
- 2 Year **Wind Data Baseline** - Installed **anemometer,** proved excellent wind resource average **13 mph, 6 m/s @ 25 m**
- Informational Meetings:
  - Local Municipalities, Universities, Private Industry
  - Suffolk County, LIPA, National Grid, Merchant Marine Academy
  - Site Visits: Hull, MA and Half Hollow Nursery

WIND ENERGY

100 kW Funding

Energy Efficiency & Conservation Block Grant (EECBG)

- **ARRA Funding –** Administered by DOE
- **$4,577,700 grant** – Assigned to Conservation & Waterways

Project Activities

- Building Audits & Retrofits – Lighting/HVAC Upgrades, Geothermal, Energy Billing Database, Marina LED Dock Lighting
- Solar PV
- Transportation – Anti-Idling Demo Project
- **Wind Turbine – 100kW**
- Energy & Sustainability Master Plan
- Outreach & Education

WIND ENERGY

Site Selection

Technical Feasibility

Wind Resource – from anemometer and Skystream 2.4kW wind turbine @ Shellfish Facility

Foundation – Test boring to 25 feet for foundation to determine soil type, groundwater elevation, weight bearing capacity

Energy Load, Innovation, Education

Hydrogen Fueling Station – new energy load, required solution, wind to hydrogen energy storage demonstration

Energy Park – great addition for outreach & education

WIND ENERGY

Site Selection

Environmental Review & Public Process

Federal NEPA – Environmental Assessment (EA) was required, project received a Finding Of No Significant Impact (FONSI)

State SEQRA – Project received a Negative Declaration

Permits

Not required on Town property, but worked very closely with the Town’s Building Department during the site selection, design and construction phases

WIND ENERGY

Turbine Selection

Northern Power (NP) 100

Gearless Direct Drive: no gearbox, generator and rotor are direct coupled, moving together at same speed = Less moving parts = lower maintenance costs

Tower Height – at 120 feet, this was a “small” wind turbine, compared to MW sizes, good fit for local community

Power Size – 100 kW was acceptable for the existing electrical infrastructure, saving on up front installation costs

Net Metering – NP100 is on the LIPA approved list for net metering, no Power Purchase Agreement required

Buy American Provision – NP is a Vermont company, met ARRA funding requirements

WIND ENERGY

Turbine Specs

Northern Power 100, Manufactured in Vermont, USA	
Tower Height	120 Feet
Rotor Diameter	70 Feet (each blade, 35 feet)
Yaw	Upwind, Electronic Control System Wind Change > 5 degrees & sustains that change for 1 minute, nacelle will yaw into the wind
Cut-In Speed	3.5 m/s (7.8 mph)
Cut-Out Speed	27 m/s (60 mph) witnessed during Sandy
Noise	55 dBA, quieter than nearby road noise
Total Cost (Design & Construction)	$613,000

WIND ENERGY **Performance**

Power Production

Commissioned December 2011	
1st Year	**221,629 kWh** (with approx.one month down time) - Enough to power ~25 Long Island homes
2nd Year	**229,442 kWh** (with approx. one month down time)
To Date (3/26/14)	**543,939 kWh**

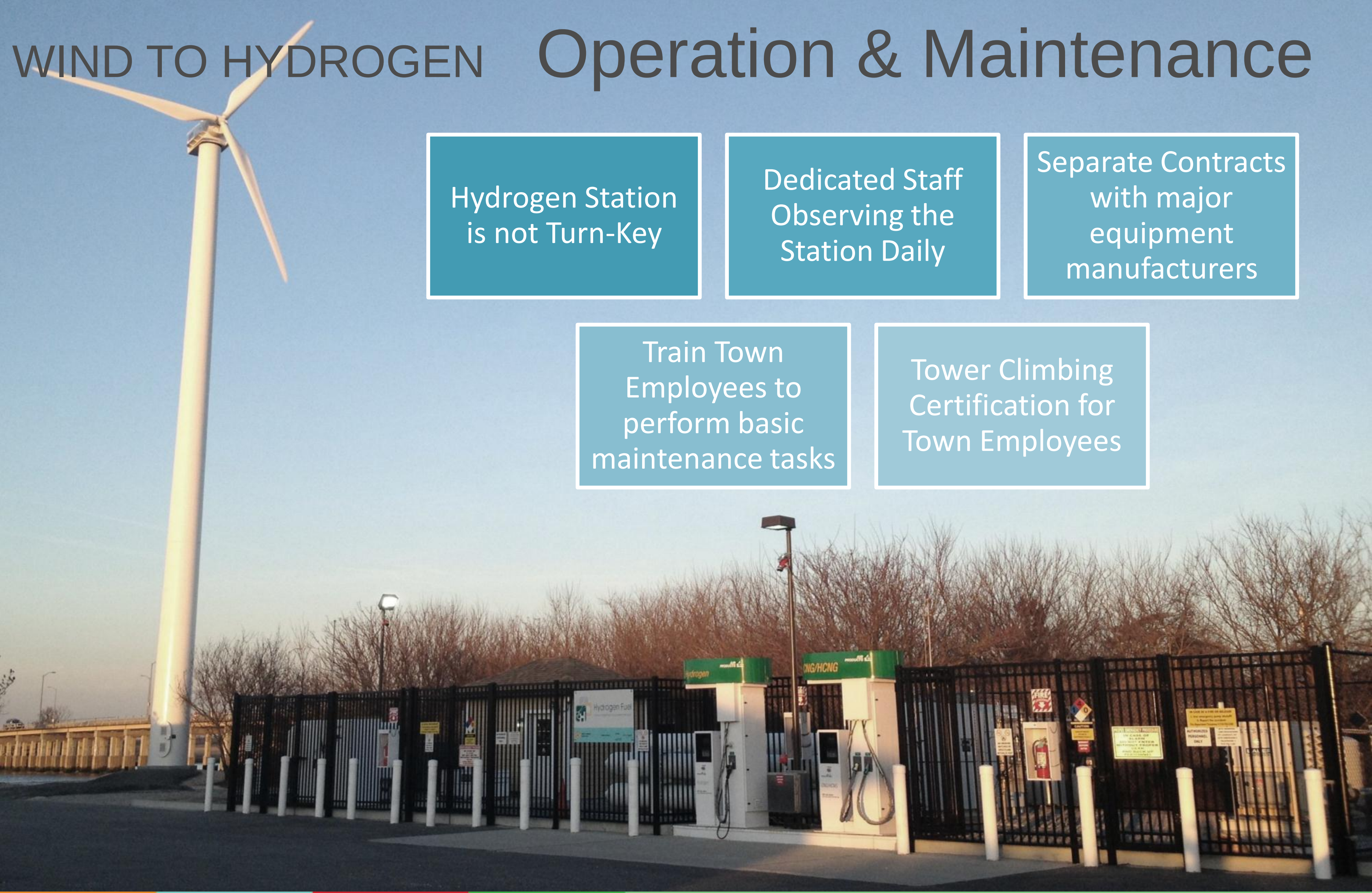
2012 EPA Environmental Quality Award

for Wind Turbine and Energy Park

WIND TO HYDROGEN

Operation & Maintenance

- Hydrogen Station is not Turn-Key
- Dedicated Staff Observing the Station Daily
- Separate Contracts with major equipment manufacturers
- Train Town Employees to perform basic maintenance tasks
- Tower Climbing Certification for Town Employees



Resiliency

Hurricane Sandy

- No damage from flooding at either wind turbine or hydrogen station
- Designed to 100 year flood elevation
- Minor flooding around base of Wind Turbine – performed post-hurricane engineering review

Future Mirogrid Opportunity

- System is net-metered – without grid power, turbine will not run
- No power for approx. 2 weeks post-hurricane
- Opportunity for microgrid demonstration in future

WIND TO HYDROGEN

Outreach & Education

NY Agricultural Women

Nassau County Bar Association

NYC Engineering Society

Utilities

Local Municipalities

Middle and High Schools

Universities

Science Summer Camps

International Visitors - Tokyo Gas, Korean manufacturing company, Chinese Engineers, Engineers from Toyota HQ in Japan


School Group Visiting Shellfish Facility

Training & Workshops

Hydrogen Safety Classes

- Provided by Air Products (fueling station installer), and Toyota (fuel cell division)
- Trained local fire departments, Fire Marshal

Hydrogen Curriculum Workshop for Teachers

- Provided by Nassau BOCES

WIND TO HYDROGEN

Next Steps for Outreach

Multimedia

- Website
- Social Media
- Videos
- Branding
- Brochures
- Signage (with Solar LED Lighting)

Formalize Curriculum and Tours

- Partner w/ local education institutions
- Establish a team to give regular tours
- Develop Labs/Activities, Worksheets

WIND TO HYDROGEN

Future Projects

Microgrid

- Integrate microgrid technology with Wind to Hydrogen project

Desalination

- Reverse Osmosis to provide potable water to NYIT Solar House

Tidal Power

- Utilize currents in Reynolds Channel to power marinas

Data Acquisition & Monitoring System

- Build out metering system and integrate with public website

TOWN OF HEMPSTEAD

PROJECT ENERGY

THANK YOU!

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Dept. of Conservation & Waterways

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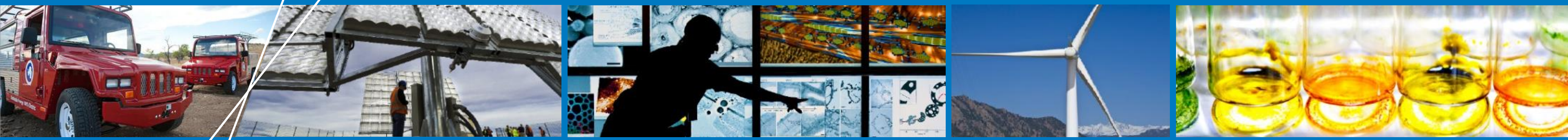
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

CESA/NEESC Webinar

Distributed Wind Technology for Hydrogen Production



Kevin Harrison

National Renewable Energy Laboratory

March 27, 2014

This presentation does not contain any proprietary, confidential, or otherwise restricted information

Outline

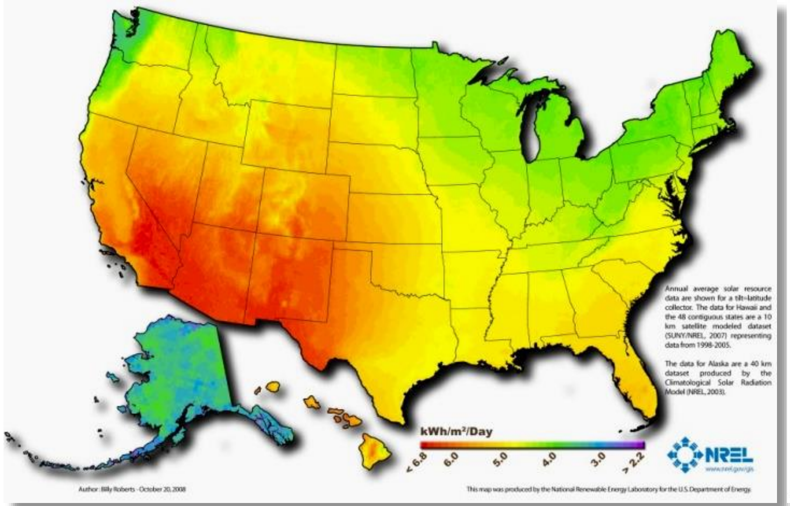
- Introduction
- Justification
- NREL's Wind-to-Hydrogen Project
- Research & Development

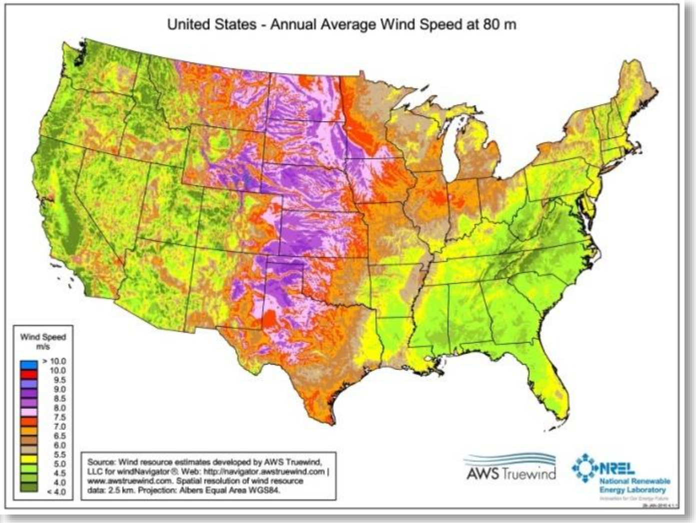
Why Renewable Electrolysis?

Hydrogen can be made in a large scale from a wide variety of energy sources

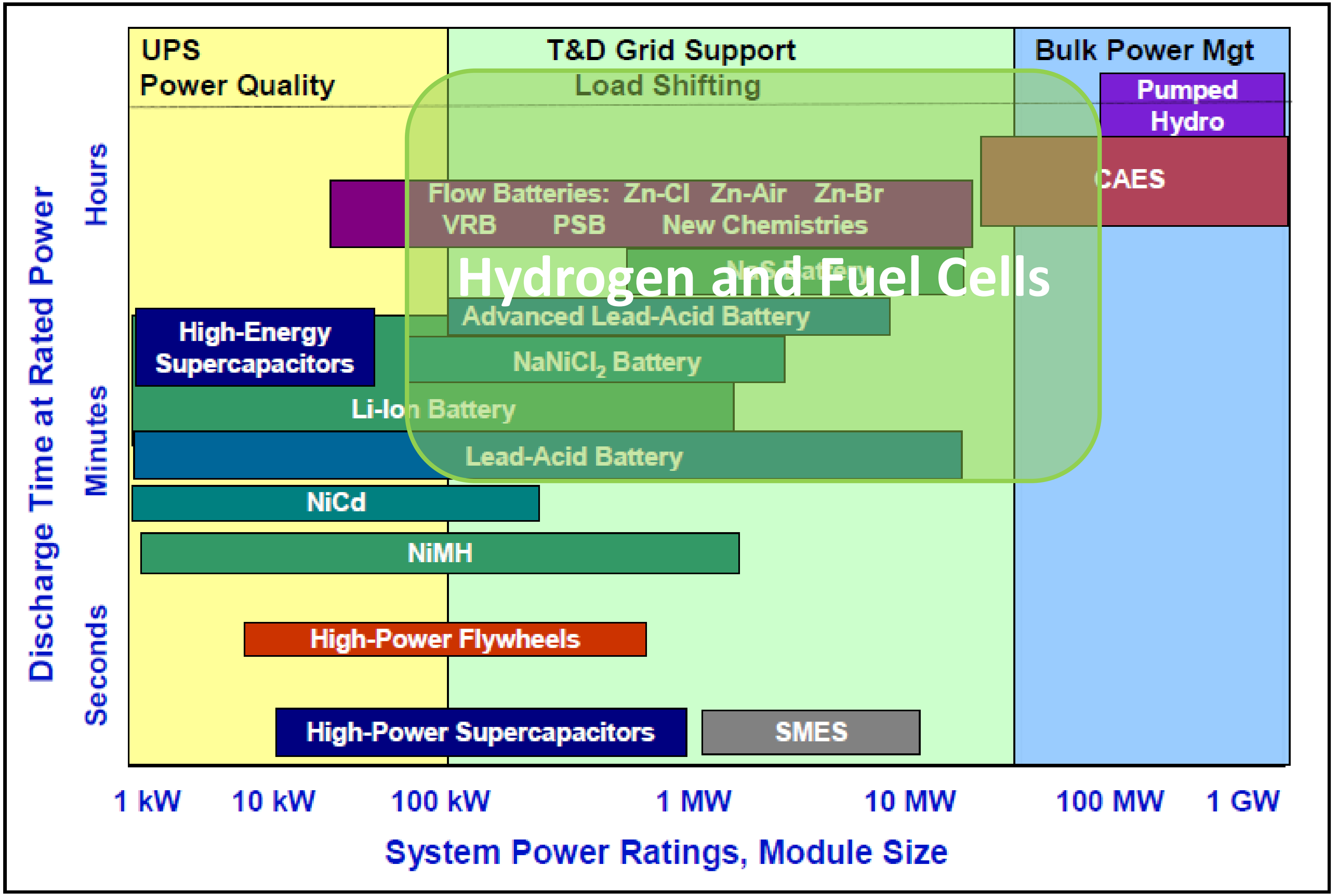
- Biomass (30 billion kg H_2/year)
- **Renewable electricity (wind, solar – 991 billion kg H_2/year)**
- Nuclear (4 billion kg/year)
- Natural gas (27 billion kg/year)
- Coal with sequestration (40 billion kg/year)

See NRC scenario utilizing diverse feedstocks for hydrogen production



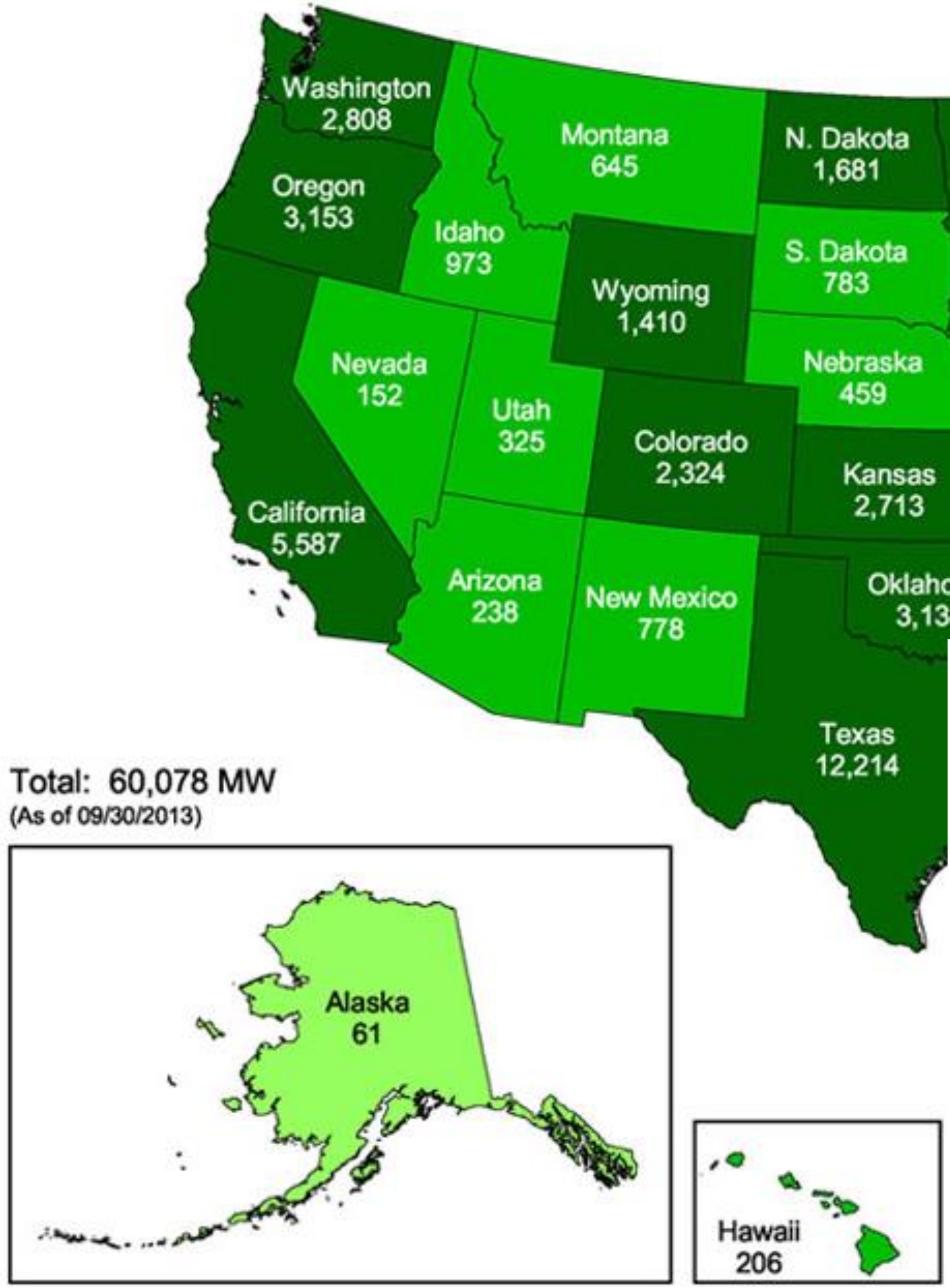


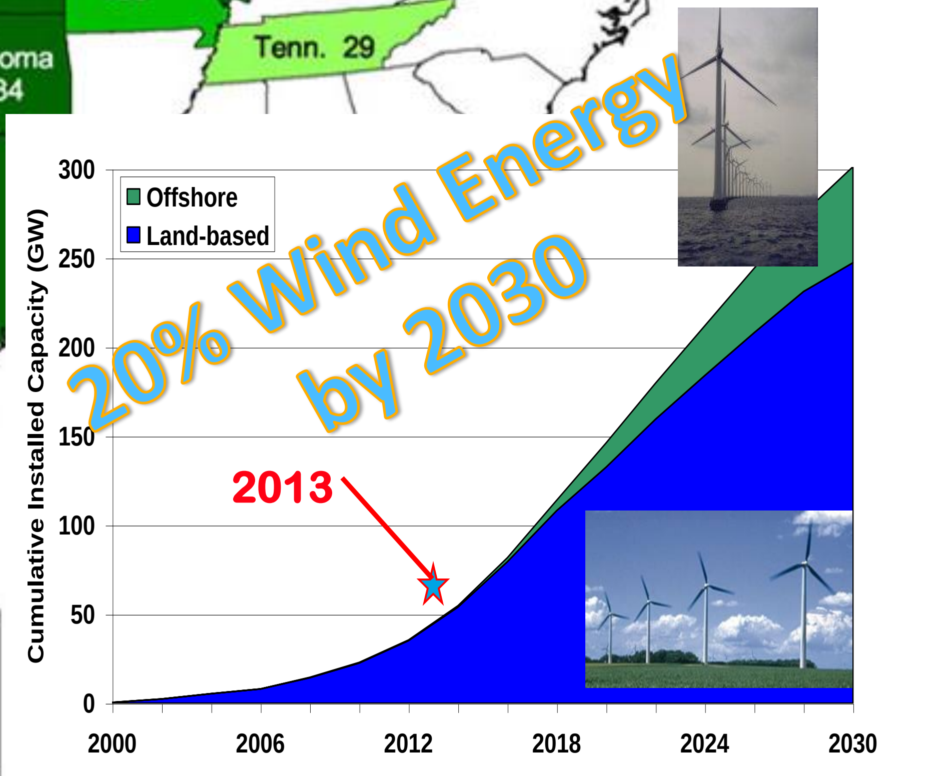
Energy Storage Technologies



http://energystorage.org/system/files/resources/sand2013-5131.pdf

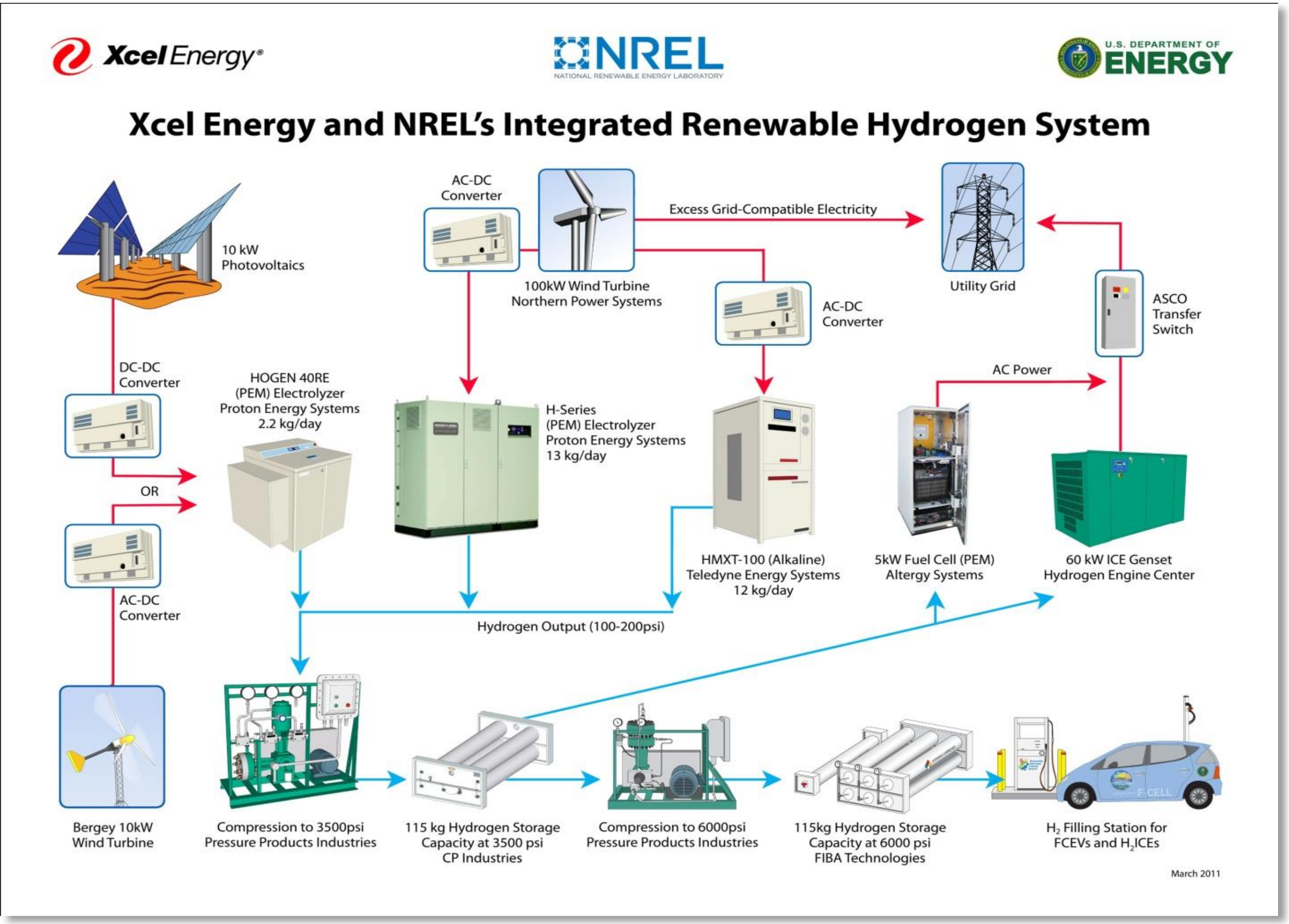
Current Installed Wind Capacity (MW)





Renewable Electrolysis - Capabilities

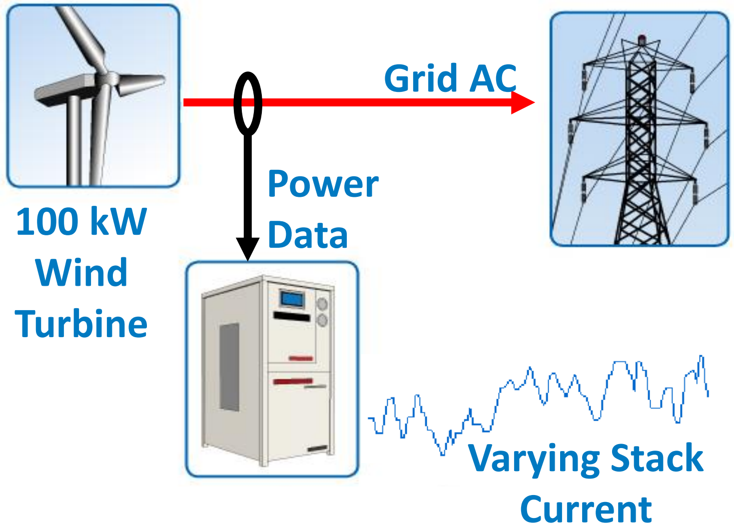
The project has evolved over the past 7 years to meet changing industry, NREL and DOE needs

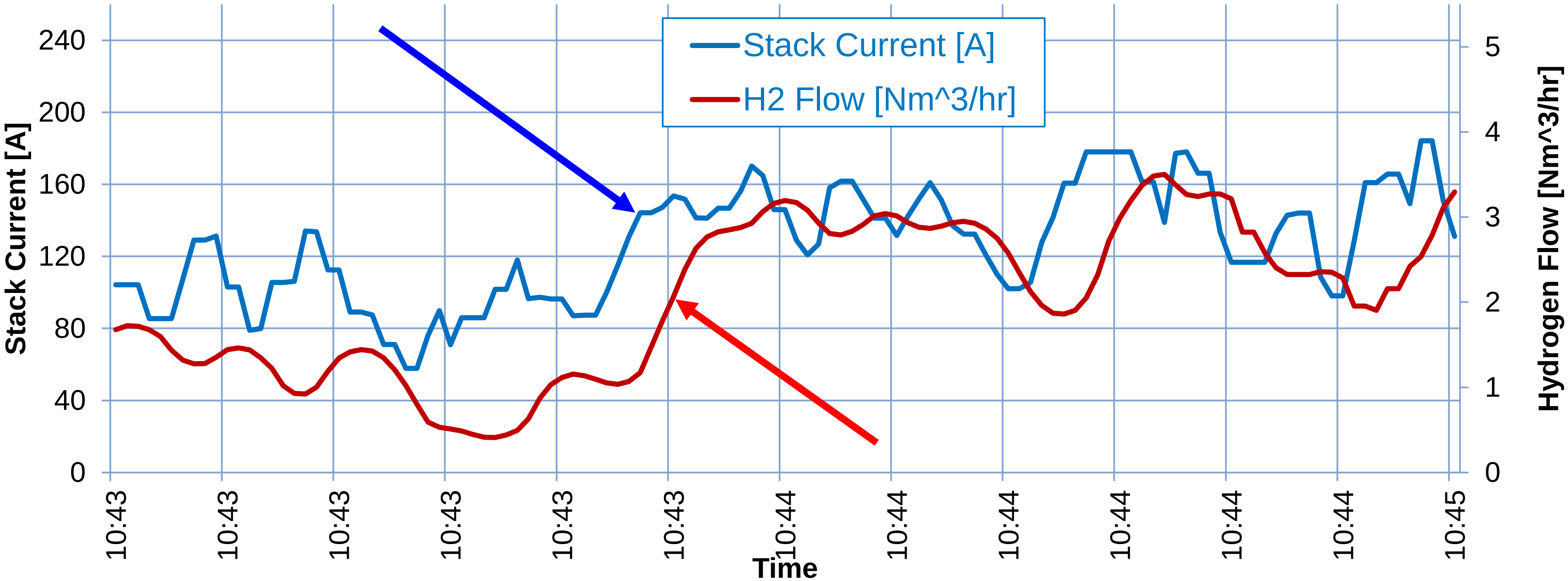


- AC/DC switchgear
- PV and Wind turbines
- 100 kW Electrolysis
  - 1 kg/hr
- 2 stages compression
- 230 kg storage
  - 240 & 400 bar
- 5 kW fuel cell
- 60 kW ICE gen-set
- 350 bar fueling

Wind Turbine to Alkaline Stack

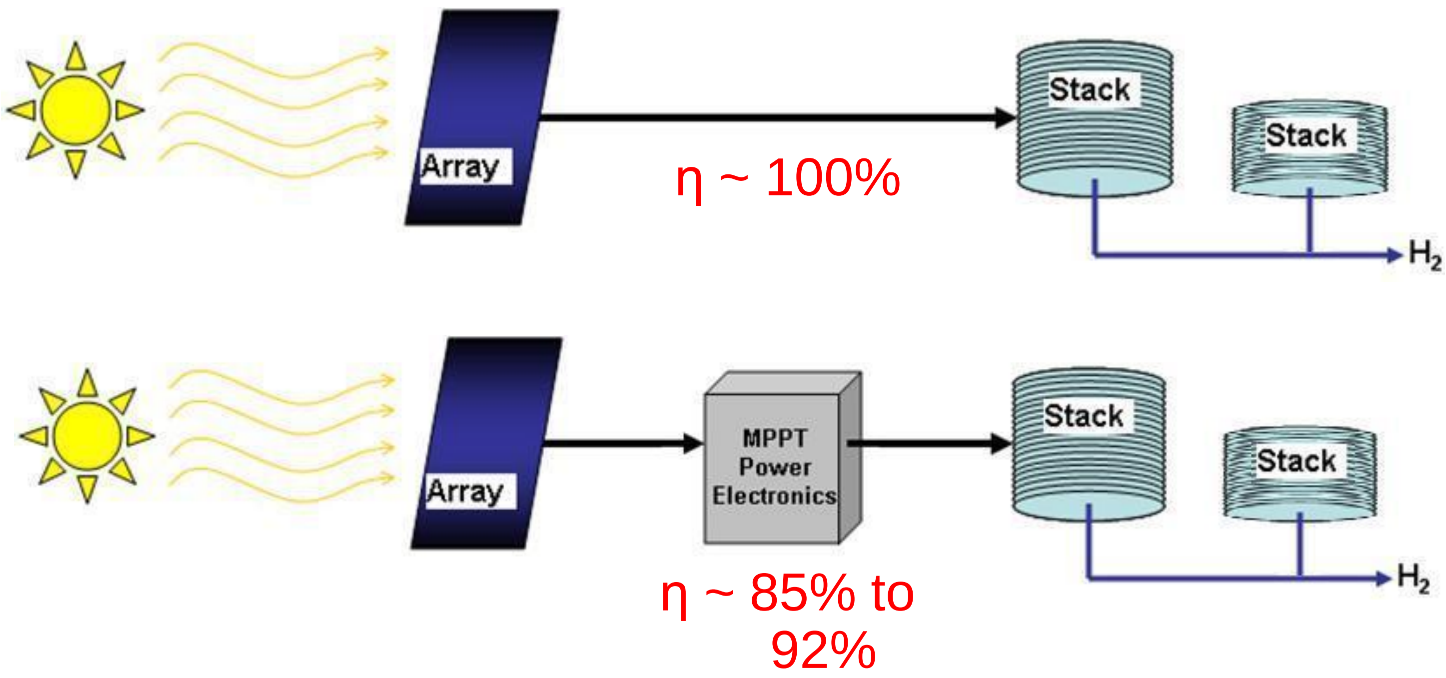
Instrumented power signal from 100 kW wind turbine to drive 33 kW alkaline stack current to follow power available from turbine

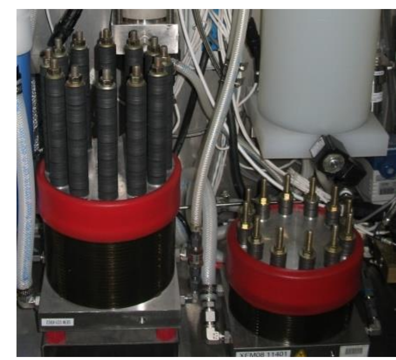




Direct-Coupling v. Power Converter

- Modified system and added ½ stack electrically in series with full stack
- Better aligned operating points of PV array and combined stacks
- Traded efficiency for maximum power point tracking

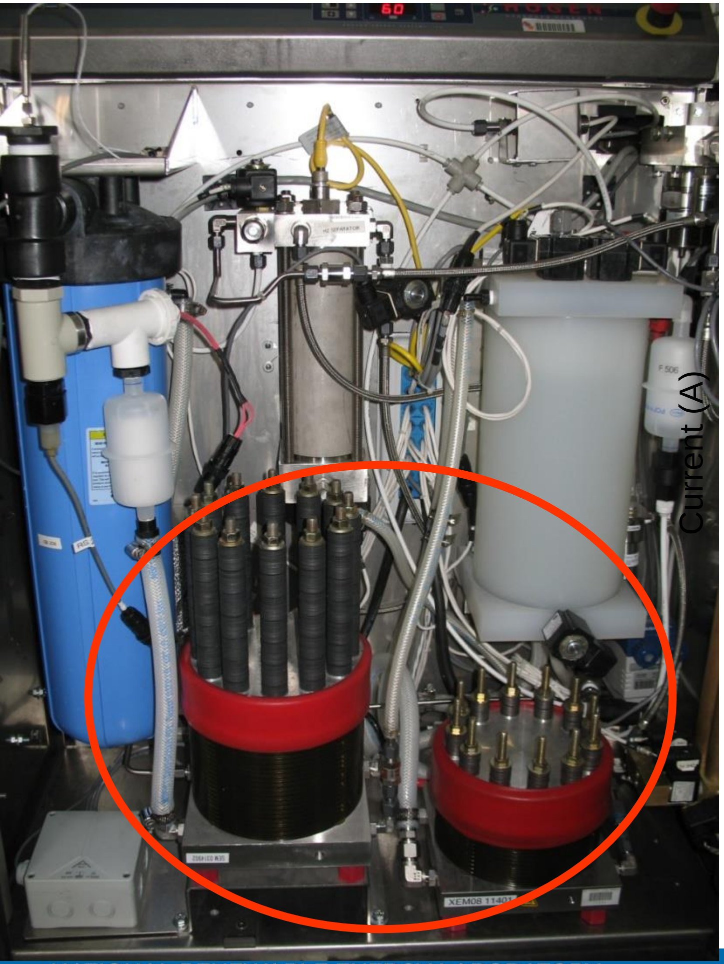


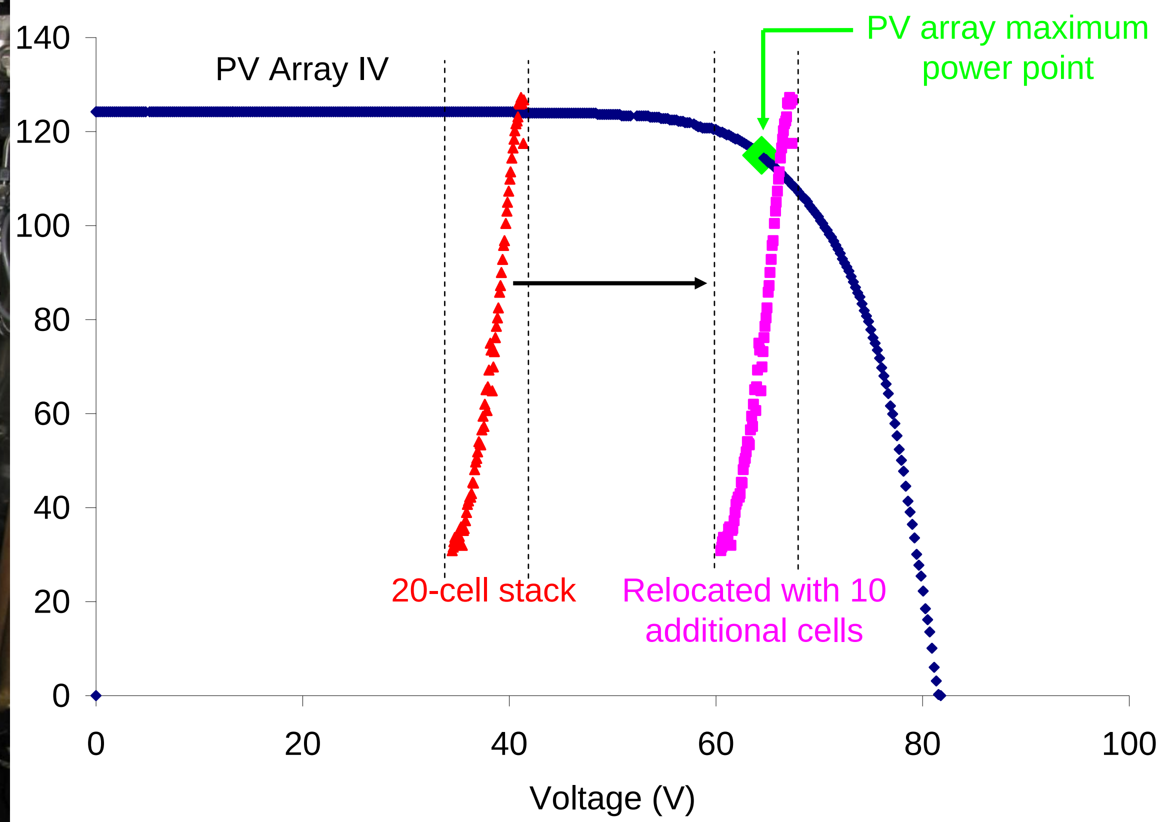


Direct-Coupling v. Power Converter

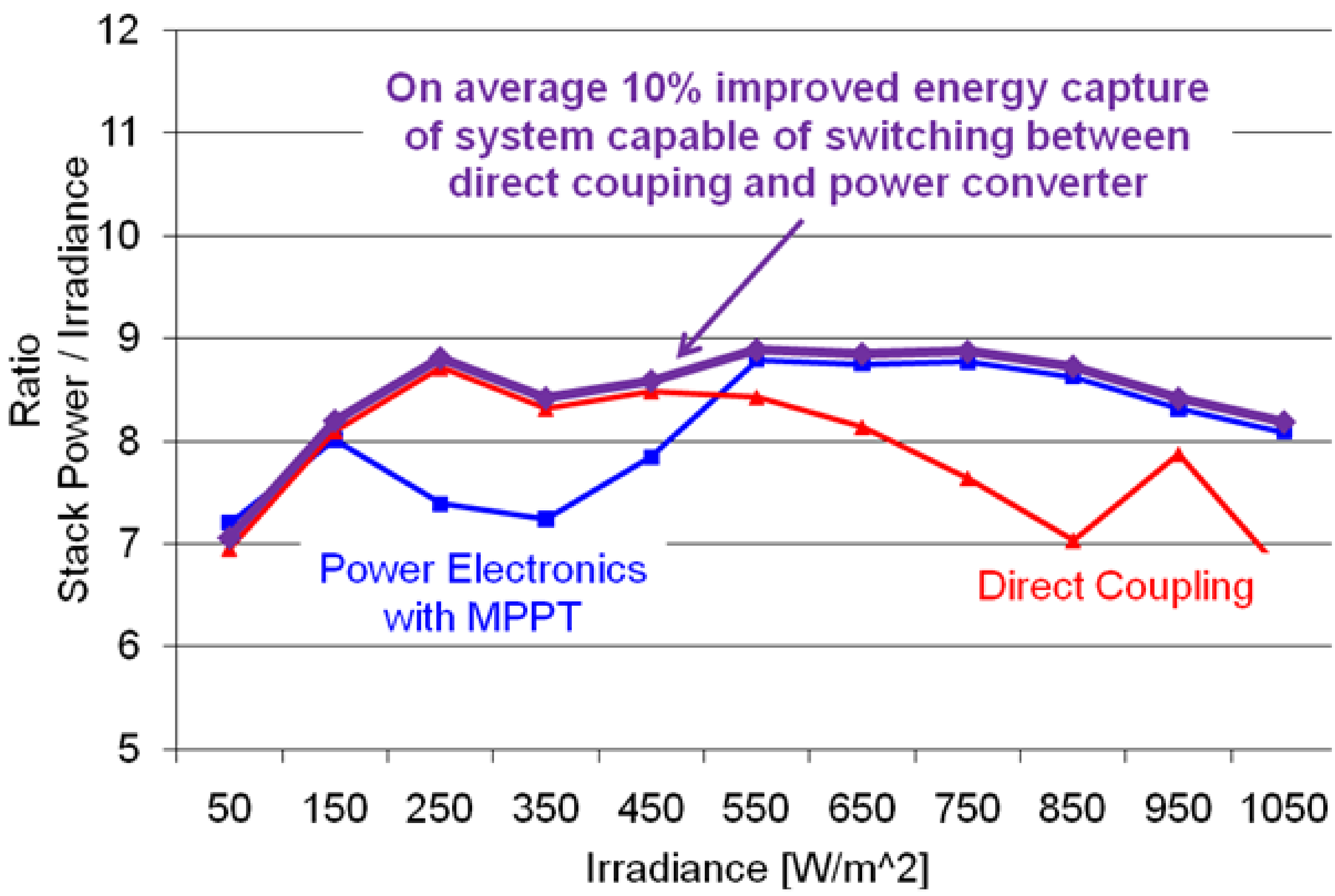
Goal: Better align PV and stack operating points

Result: Additional 10-cell stack (electrically) in series with original 20-cell stack shifted stacks IV curve to the MPP of the PV array

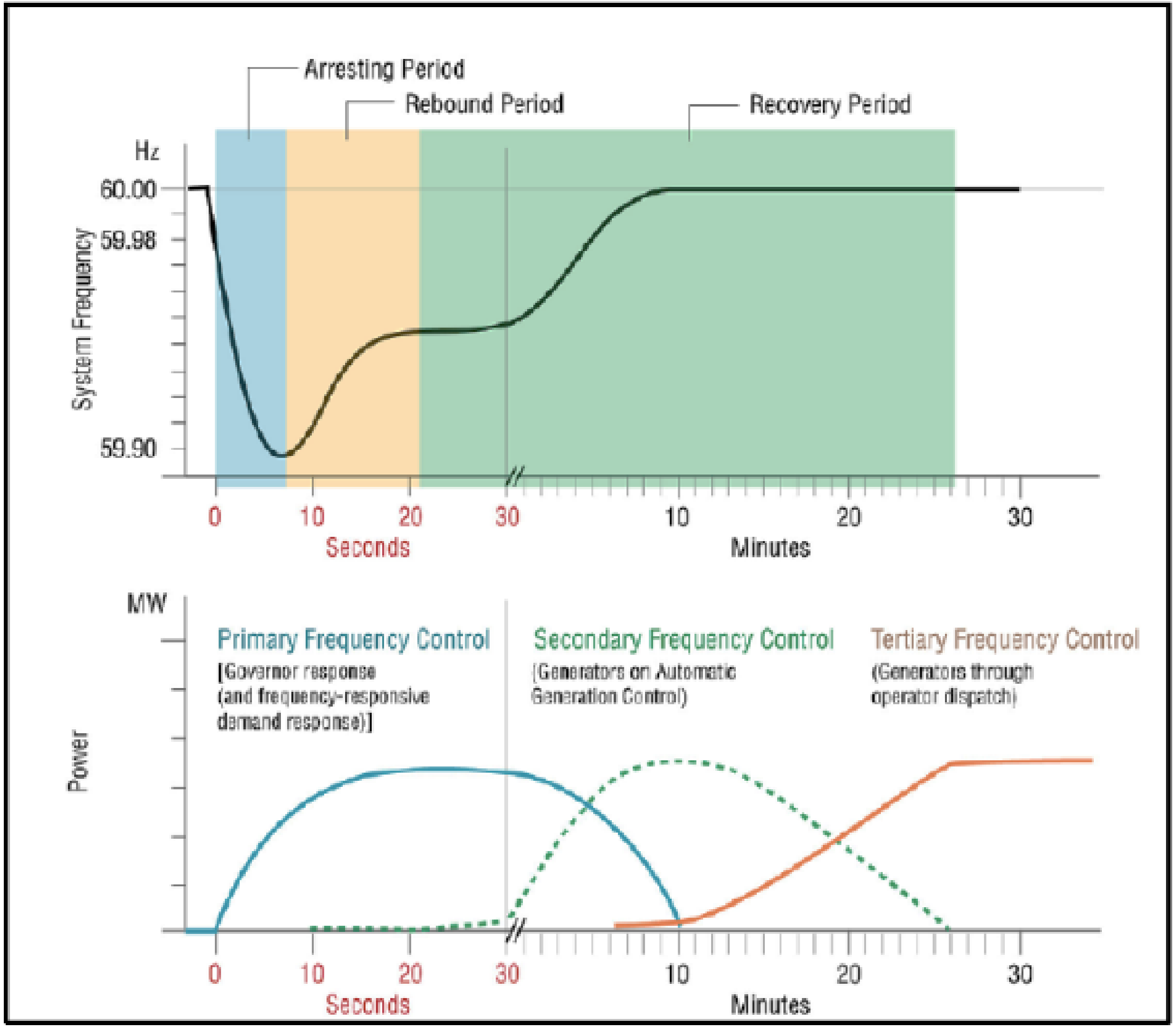




Direct-Coupling v. Power Converter



Frequency Control



The Sequential Actions of Primary, Secondary, and Tertiary Frequency Controls Following the Sudden Loss of Generation and Their Impacts on System Frequency

http://energy.gov/sites/prod/files/2013/12/f5/Grid%20Energy%20Storage%20December%202013.pdf

Electrolyzer – Grid Frequency Support

Experimental Setup showing AC micro-grid configuration to test frequency response of PEM and alkaline electrolyzers

Electrolyzers have the potential to realize an additional revenue stream by providing ancillary grid support services

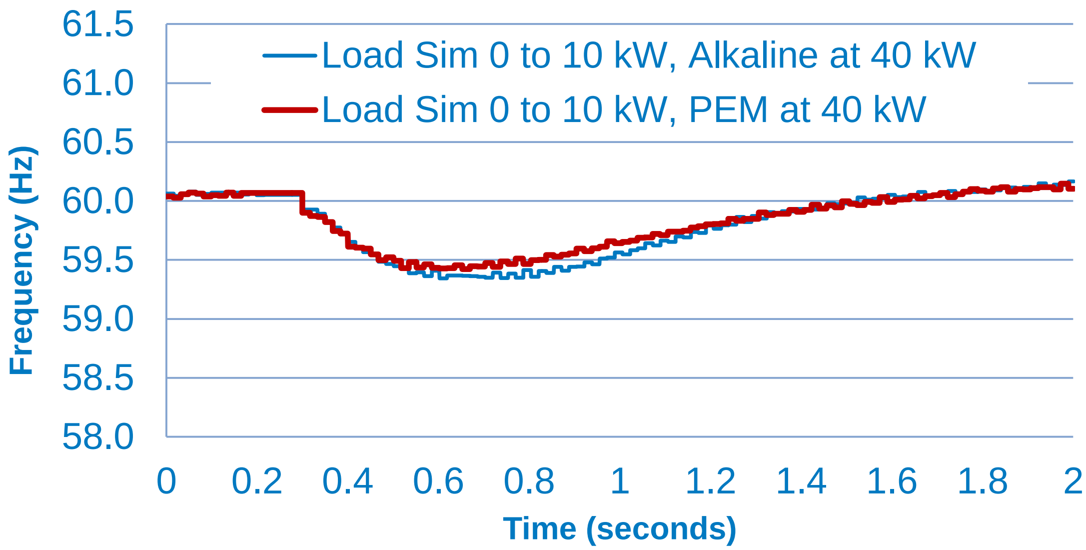
AC micro-grid

Experimental Setup

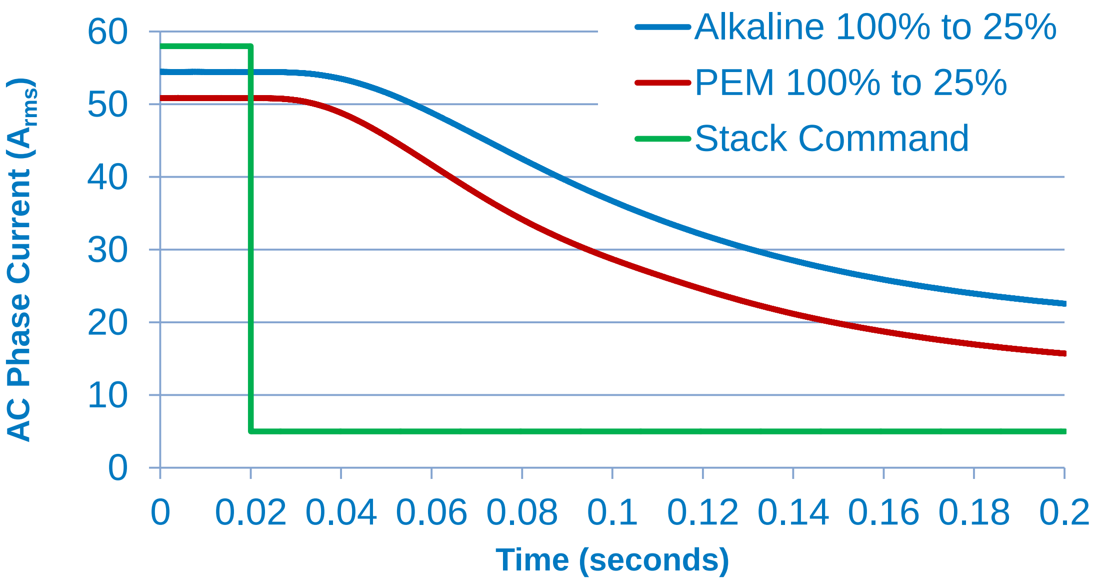
- 120 kW diesel generator powering electrolyzers
- Load simulator adding or shedding load to induce frequency disturbances
- Electrolyzers commanded to shed or add stack power
  - Micro-grid monitored and electrolyzer command initiated when frequency exceeded ± 0.2 Hz

Electrolyzer – Grid Frequency Support

‘Natural’ un-mitigated frequency disturbances on AC micro-grid caused by 10 kW resistive load step while powering the alkaline and PEM electrolyzer

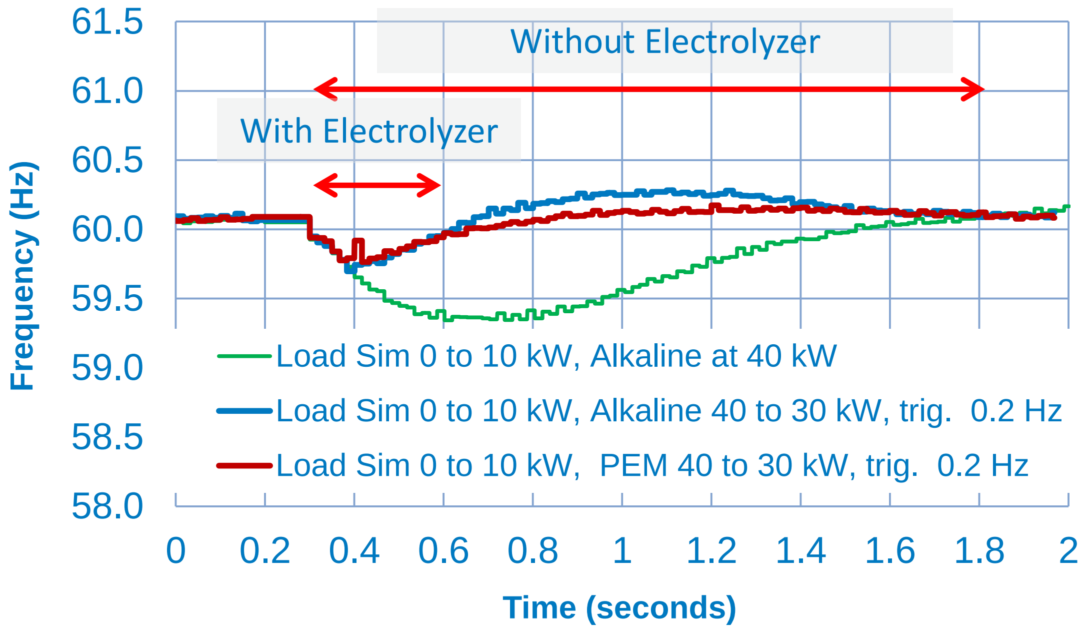


PEM and alkaline system-level response showing AC phase current (rms) to command to shed stack power (100% down to 25% of their rated power)

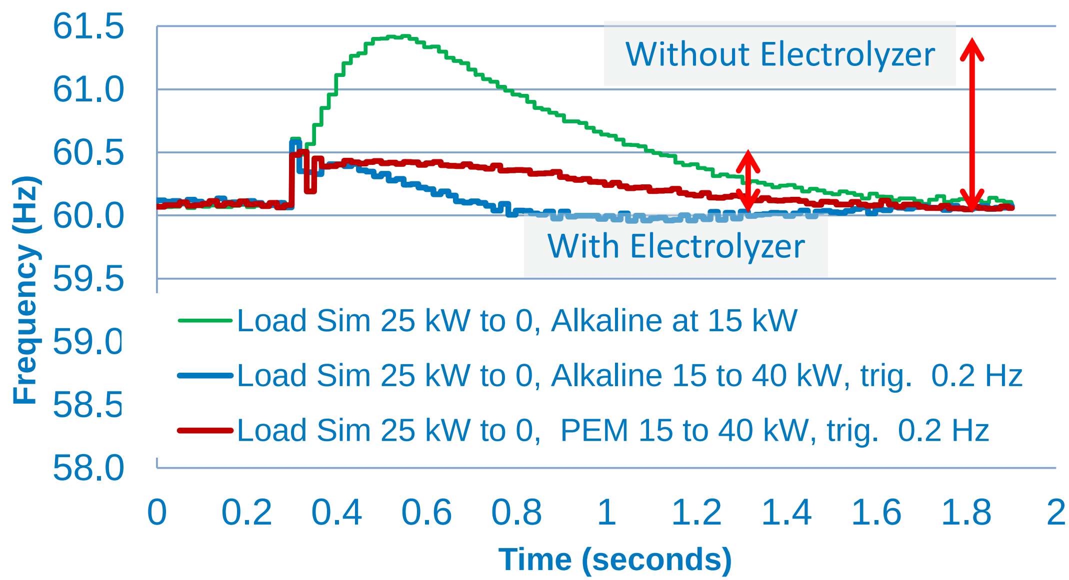


Electrolyzer – Grid Frequency Support

10 kW steps -PEM and alkaline systems shorten magnitude and duration of under-frequency disturbance on AC micro-grid



25 kW steps - PEM and alkaline systems shorten and reduce magnitude of over-frequency disturbance on AC micro-grid



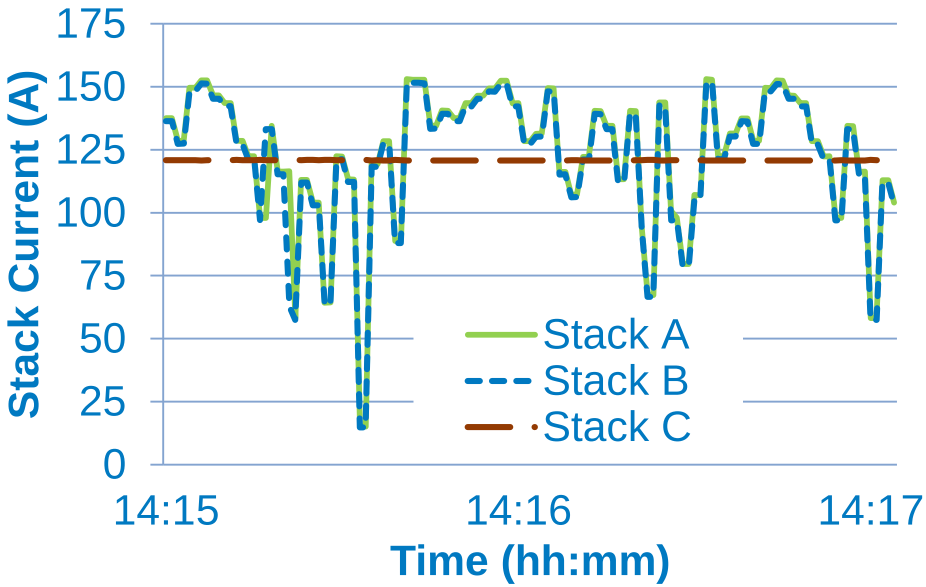
Decay Rate – Variable Power Stack Testing

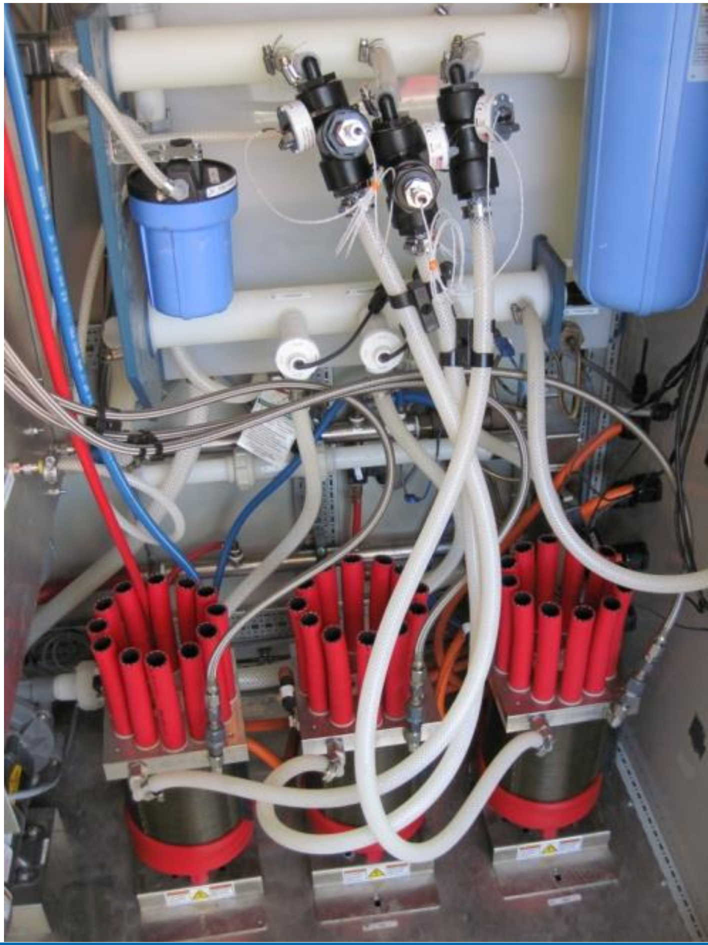
Summary – Completed 10,000 hours on neglected stacks. Variable and constant power decay rates were within 10%.

Path Forward – Two new stacks installed. (1200 hours to date)

Monitoring and Control

- Stack input and output temperature
- Stack voltage and current
- Individual control over each of 3 stacks
- Programmable wind/solar profiles





Thank you!

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Wind-to-Hydrogen website

http://www.nrel.gov/hydrogen/proj_wind_hydrogen.html

Or search "Wind to hydrogen NREL"

References

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